SITE SELECTION PROCESS - PHASE 4A:
SELECTION OF A PREFERRED SITE(S)
GEOLOGIC, HYDROGEOLOGIC, AND
GEOTECHNICAL CONSIDERATIONS

FOR

ONTARIO WASTE MANAGEMENT CORPORATION

BY

GARTNER LEE ASSOCIATES LIMITED

PROJECT: 85-S18.3
DISTRIBUTION:
2 c.c. Client
3 c.c. File

OCTOBER, 1985.

Gartner Lee
Associates Limited

Gartner Lee Associates Limited

Consulting Engineering
Geologists
Biologists and
Hydrogeologists

Toronto-Buttonville Airport ■ Markham, Ontario ■ L3P 3J9 ■ 416-477-8400
Telex-06-986278

October 3, 1985.

Dr. B.D. Mitchell,
Director of Corporate Planning
and Development,
Ontario Waste Management Corporation,
2 Bloor Street West,
11th Floor,
Toronto, Ontario,
M4W 3E2.

Attention: Mr. J.G. Micak,
Manager, Environmental Planning

Dear Dr. Mitchell:

Re: Final Report, Site Selection Process Phase 4A:
Selection of a Preferred Site(s) Geologic,
Hydrogeologic, and Geotechnical Considerations

We are pleased to submit our final report for the above noted project.

The main body of the report is found in this document and contains our work scope, approach, phase 4A factors and the results of the comparative evaluation of the eight candidate sites. Accompanying this report are eight separate technical appendices, discussing the geologic, hydrogeologic, and geotechnical setting of each of the eight sites. These technical appendices contain the data base used in this comparative evaluation.

Once again we thank you for allowing us to be of service on this most interesting project.

Yours very truly,

GARTNER LEE ASSOCIATES LIMITED

Grant Anderson

E.G. Anderson, P.Eng.,
Project Director.

GHF:jcm

TABLE OF CONTENTS

PAGE

Letter of Transmittal
Table of Contents (i)
Executive Summary (v)
Study Team (viii)

1.0 INTRODUCTION 1
1.1 BACKGROUND 1

1.2 PURPOSE AND SCOPE 3
1.2.1 PURPOSE 3
1.2.2 SCOPE OF EARLIER GEOLOGIC/HYDROGEOLOGIC STUDIES (PHASES 1 TO 3) 5
1.2.3 SCOPE OF THIS STUDY (PHASE 4A) 7

1.3 APPROACH 9

1.4 FACILITY CHARACTERISTICS 16
1.4.1 ENGINEERED LANDFILL 17
1.4.2 CENTRAL OPERATING AREA 20

1.5 REPORT FORMAT 22

2.0 REFINEMENT OF SITING OPTIONS 24
2.1 INTRODUCTION 24

2.2 REFINEMENT OF SITE BOUNDARIES 25
2.2.1 FACTOR IDENTIFICATION 26
2.2.2 FACTOR APPLICATION 27

2.3 ACCESS ROAD OPTIONS 31
2.3.1 FACTOR IDENTIFICATION 32
2.3.2 FACTOR APPLICATION 33

2.4 RAIL ACCESS OPTIONS 34
2.4.1 FACTOR IDENTIFICATION 38
2.4.2 FACTOR APPLICATION 39

3.0 COMPARISON OF SITING OPTIONS 41
3.1 INTRODUCTION 41

PAGE

3.2 COMPARATIVE METHODOLOGY 44
3.2.1 FACTOR IDENTIFICATION 44
3.2.2 INDICATOR IDENTIFICATION 48
3.2.3 DATA COLLECTION 61
3.2.4 DATA MATRICES 63
3.2.5 INDICATOR SCREENING, SCALING AND AGGREGATION 63

3.3 APPLICATION OF FACTORS FOR COMPARISON OF SITING OPTIONS 73
3.3.1 CAPABILITY OF PROVIDING NATURAL CONTAINMENT FACTOR 73
3.3.2 IMPACT ON GROUND WATER USE FACTOR 88

3.4 FACTOR AGGREGATION AND RANKING 88

3.5 RANKING OF SITING OPTIONS 93

3.6 CONSIDERATIONS FOR ENHANCING SITE SUITABILITY 101
3.6.1 ALTERNATIVE LANDFILL DESIGN CONSIDERATIONS 101
3.6.2 ADJUSTMENTS TO FACILITY PLACEMENT 103

4.0 CONCLUSIONS AND RECOMMENDATIONS 104

5.0 REFERENCES 107

APPENDICES

APPENDIX A - ASSESSMENT OF CONTAMINANT MOVEMENT THROUGH THE CONFINING LAYER

APPENDIX B - OWMC PHASE 4A - FACTORS FOR SITE SELECTION

APPENDIX C - BASE MAPS SHOWING REFINED BOUNDARIES, ACCESS ROAD OPTIONS AND RAIL ACCESS OPTIONS

APPENDIX D - DATA MATRICES

TECHNICAL APPENDICES - CANDIDATE SITES DATA (Separate Volumes)

FIGURES

		PAGE
1.	FACILITIES DEVELOPMENT PROCESS - PHASE 4A: SELECTION OF A PREFERRED SITE	2
2.	LOCATION OF CANDIDATE SITES	4
3.	SITE SELECTION PROCESS - GEOLOGIC/ HYDROGEOLOGIC ROLE	6
4.	GROUND WATER PATHWAYS AND WATER USE	11
5.	CONFINING LAYER THICKNESS AT LF-1E	28
6.	CONFINING LAYER THICKNESS AT LF-3C	29
7.	CONFINING LAYER THICKNESS AT PI-1N	30
8.	EVALUATION PROCESS FOR COMPARISON OF SITING OPTIONS	43
9.	DEVELOPMENT OF APPLIED INDICATORS FOR CAPABILITY OF PROVIDING NATURAL CONTAINMENT FACTOR	51
10.	DEVELOPMENT OF APPLIED INDICATORS FOR IMPACT ON GROUND WATER USE FACTOR	52
11.	DATA COLLECTION METHODOLOGY FLOW CHART	62
12.	COMPARISON OF SITING OPTIONS	78

TABLES

1.	FACTORS USED IN THE REFINEMENT AND COMPARISON OF SITING OPTIONS	14
2.	HYDROGEOLOGIC RANKING OF ACCESS ROAD OPTIONS	35
3.	HYDROGEOLOGIC RANKING OF RAIL ACCESS OPTIONS	40
4.	EXISTING GROUND WATER USE ONSITE AND IN SITE VICINITY (Based on Walk and Talk Survey)	59

PAGE

5. SUMMARY OF POTENTIAL MAN-MADE CONTAMINANT PATHWAYS AT CANDIDATE SITES 65

6. SCALING SYSTEMS APPLIED TO INDICATORS OF 'CAPABILITY OF PROVIDING NATURAL CONTAINMENT' FACTOR 67

7. SCALING SYSTEMS APPLIED TO INDICATORS OF IMPACT ON GROUND WATER USE FACTOR 68

8. SUMMARY DEFINITIONS OF FACTOR SUITABILITY RATINGS 74

9. SUMMARY OF SUITABILITY RATING FOR 'CAPABILITY OF PROVIDING NATURAL CONTAINMENT' FACTOR 80

10. SUMMARY OF SUITABILITY RATING FOR 'IMPACT ON GROUND WATER USE' FACTOR 89

11. RANKING OF SITING OPTIONS 94

12. CONTAMINANT BREAKTHROUGH TIMES, LF-3C AND LF-9C 95

13. CONTAMINANT BREAKTHROUGH TIMES, LF-1E 96

14. CONTAMINANT BREAKTHROUGH TIMES, PI-27E 98

15. CONTAMINANT BREAKTHROUGH TIMES, PI-1N 100

16. SITES WHICH CAN POTENTIALLY ACCOMMODATE THE VARIOUS LANDFILL DESIGN ALTERNATIVES 102

EXECUTIVE
SUMMARY

PURPOSE OF THE REPORT

Geologic, hydrogeologic, and geotechnical studies were undertaken by Gartner Lee Associates Limited in support of Phase 4A of Ontario Waste Management Corporation's (OWMC) Site Selection Process. This report and accompanying appendices provide:

- the technical data base developed for the eight candidate sites during Phase 3B and Phase 4A;

- the documentation of the methodology used in the comparative evaluation of the geologic, hydrogeologic, and geotechnical settings of the candidate sites; and

- the rationale for the identification of a preferred site(s) based on geologic, hydrogeologic and geotechnical considerations.

SCOPE AND METHODS

The scope, scale, and methodology employed in the investigation of the eight candidate sites are described in Sections 1.0, 2.0 and 3.0 These investigations consisted of:

- compilation of secondary source information from published and unpublished studies;

- field mapping and discussion with citizen groups to gain a better appreciation of site conditions and local knowledge;

- limited drilling on each site to improve the data base on subsurface conditions;

- office analysis of the collected data;

- discussion of the site geologic/hydrogeologic setting with citizen groups and feedback to assist in final site descriptions;

- meetings with public interest groups and citizens at formal workshops to discuss factor selection and ranking;

- regularly scheduled meetings with the consultant team and client to facilitate incorporation of the geologic, hydrogeologic and geotechnical data into the overall selection of a preferred site(s);

- documentation of the entire process in this report and the accompanying appendices.

The process of identifying a preferred site(s) was guided by the following three OWMC goals to:

- minimize risk to human health;

- minimize environmental impacts; and

- minimize financial costs to OWMC and the people of Ontario.

The methodology used in comparison of the siting options included:

- the identification of site selection factors which could be used in the collection of data and in the identification of potential risks associated with facility development and operation;

- the collection, compilation and analysis of geologic, hydrogeologic and geotechnical data to establish existing site conditions; and

- the comparison of siting options based on the natural capability of the hydrogeologic setting to contain potential contaminant releases from OWMC facilities, and on the characteristics of the ground water resources potentially affected by the contaminants and alternatives to these resources;

Included in the comparison of the siting options was an evaluation of the individual sites to establish their basic acceptability (Section 3.0). The basic acceptability analysis involved the identification of major constraints as a result of new information collected during the Phase 4A studies, which could preclude the use of a site. From a hydrogeologic perspective, the failure of a site to provide natural containment of potential contaminants is viewed as a major constraint to facility development. Where such containment is identified as being non-existent, the site is not considered to be capable of providing the second level of protection of the environment desired by OWMC. The final comparison of siting options is limited to those sites and combinations of sites which are basically acceptable.

Information on site specific geotechnical considerations were provided to the engineering consultant, Monenco Limited and was used in their cost comparison of siting options and in their analysis of site landfilling capacity. The reader should refer to the report titled Site Selection Process, Phase 4A: Selection of a Preferred Site(s) - Engineering (Monenco Limited, 1985b) for a discussion of how this information was used.

PREMISES AND POSTULATES

The general approach followed during Phase 4A including the identification and evaluation of siting options and alternatives within each option in a form suitable for integration into the overall site selection process was coordinated by M.M. Dillon Limited. The identification of the appropriate scope and scale of the study, and the approach to data collection and analysis were established by the individual technical consultants in consultation with M.M. Dillon Limited and OWMC staff. Information on facility characteristics and contaminants which may potentially be released from these facilities was provided by Monenco Limited, M.M. Dillon Limited and OWMC staff.

The reader should refer to the report titled Site Selection Process, Phase 4A: Selection of a Preferred

Site(s) - Site Selection (M.M. Dillon Limited, 1985a) for a detailed discussion of the site selection process. Facility characteristics are provided in the Monenco Reports titled Status Report, Facility Design (Monenco Limited, 1985a) and Site Selection Process, Phase 4A: Selection of a Preferred Site(s) - Engineering (Monenco Limited, 1985b)

Each siting option includes either a single site (fully integrated), where all facility components are located at the same site, or separate sites (partially integrated) where the physical/chemical treatment plant facilities could be located with either the landfill or the incinerator. Also considered are access roads both to the site(s) from 400 series highways and between sites for intersite transfers. Proposed site acquisition boundaries were established by OWMC as a result of the Phase 3B analysis. Access road options were identified by M.M. Dillon Limited both during Phase 3B and during the initial stages of Phase 4A.

FACILITY CHARACTERISTICS

Key facility characteristics are identified in the engineering reports titled Status Report, Facility Design (Monenco Limited, 1985a) and Site Selection Process, Phase 4A: Selection of a Preferred Site(s) - Engineering (Monenco Limited, 1985b). Characteristics used in the hydrogeologic Phase 4A analysis are provided below. A more complete discussion and listing of the facility characteristics used in assessing ground water flow and contaminant transport are provided in Appendix A.

- the engineered landfill will consist of a number of separate cells or trenches adapted to the conventional design; solidified material will be placed in excavations extending to 10 m in depth and filling will continue to form a mound to 12 m in height above original grade; alternative landfill design concepts (i.e. shallow entombed and above ground) were also considered for site enhancement purposes;

- a minimum 50 m buffer zone will be left between the landfill development area and the site acquisition boundary (layout maps provided by Monenco Limited, 1985b);
- the landfill will accept only treated residues which will be primarily inorganic in nature;
- the central operating area will include a physical/ chemical treatment plant, a rotary kiln incineration plant and a solidification plant;
- untreated wastes will be handled, stored and treated in the central operating area for only a finite length of time, this time being governed by the active life of the facility which for purposes of modelling contaminant transport is assumed to be 20 years;
- facilities in the central operating area will include excavations for tanks, pits, ponds, sewers and pipes which will not exceed 8 m in depth; this depth was adjusted to 5 m, where required to enhance natural containment.

CONTAMINANT CHARACTERISTICS AND POTENTIAL CONTAMINANT RELEASE ASSUMPTIONS

The following simplifying assumptions on contaminant characteristics and release were used in the assessment of contaminant transport:

- leachate will be produced as a result of infiltrating precipitation and ground water coming in contact with the solidified mass in the landfill;

- the leachate could contain trace quantities of organic and inorganic contaminants which could represent a health and/or environmental concern;

- for worst case analysis, it is assumed that leachate is not collected and is in direct contact with the natural geologic features at each site;

- the potential exists for untreated wastes which represent a health and/or environmental concern, to be released as leaks or spills in the central operating area;

- contaminants released from the facilities are conservatively assumed to be non-reactive with the in situ soils; these contaminants are also assumed to be dilute and in solution in the ground water; and

- dilution available in the underlying aquifers was conservatively not considered in reduction of contaminant concentrations.

STATUS OF DATA

The information base assembled during Phase 4A included:

- data collected during earlier phases such as water well records, published and unpublished reports and maps;

- data collected as a result of interviews with government agency personnel and local residents, in particular information on ground water use and potential contaminant pathways;

- geology data collected during site drilling and site visits; and

- hydrogeologic and geotechnical data on the hydraulic and geotechnical properties of geologic materials similar to those present at the sites (information from published and unpublished studies).

A detailed discussion of the methodology is provided in the eight separately bound site reports (identified as technical appendices).

It should be noted that the results of the drilling program were used primarily to confirm the hydrostratigraphic interpretation developed during Phase 3B and to evaluate the predictability and uniformity of subsurface conditions. The hydrogeologic analyses utilized not only the information base described above but also information published by researchers in similar hydrogeologic settings, and the experience of Gartner Lee Associates Limited staff.

In the assessment of ground water flow and contaminant transport, mathematical models were used to simulate complex natural processes. The results of these simulations should not be interpreted as predictions of actual hydrogeologic performance under real life conditions. However, because the site selection process is comparative, the limitations inherent in the models and input parameters are applied equally at each of the sites. Characteristics and limitations of the models are described in greater detail in Appendix A.

The information to be collected during Phase 4B (highlighted in Section 4.0) will be suitable for a more detailed assessment of ground water flow and contaminant transport at the preferred site(s).

FINDINGS AND CONCLUSIONS

Four factors were identified. Two factors 'Confining Layer Thickness' and 'Distance Through Hydrogeologically Sensitive Lands' were used in refinement of site boundaries and in the identification of preferred access road and rail access options, respectively. The remaining two factors 'Capability of Providing Natural Containment' and 'Impact on Ground Water Use' were used in the comparison of siting options.

Site boundaries were refined for three sites, LF-3C, LF-1E and PI-1N. To accommodate this, portions of the sites which are preferred for facility development were identified to the site selection team.

In the identification of preferred access road and rail access options, the hydrogeology factor was applied to identify those options with the shortest distance through sensitive lands. In the event of accidental spillage of waste during transport, spills are expected to be attended to promptly. This would reduce the likelihood of contaminants migrating any distance from the spill site through the subsurface.

The comparison of siting options involved an initial evaluation of the individual sites to establish their basic acceptability. Based on this analysis two sites, first LF-2N and later PI-13N, were identified as not providing a second level of protection of the environment.

The final comparison of siting options was limited to five options (representing 6 sites). The process used in the comparison of the options is described in Section 3.0. The ranking of the options is based on:

- the extent to which the hydrogeologic setting provides natural containment of contaminants which may potentially be released at the proposed OWMC facilities (accommodated by the 'Capability To Provide Natural Containment' factor); and

- the characteristics of the ground water resources potentially affected by contaminant releases and the availability of alternative ground water supplies (accommodated by the 'Impact on Ground Water Use' factor).

The ranking, based on the above considerations, from the most preferred to least preferred is as follows:

LF-3C
LF-9C

LF-1E and LF-1E/PI-27E (ranked approximately equal)

LF-4N/PI-1N

LF-3C and LF-9C, the highest ranked siting options are both underlain by a thick, uniform confining layer. These two siting options also provide the greatest flexibility, from a hydrogeologic perspective, in being able to accommodate alternative landfill designs which are under consideration.

Siting options LF-1E and LF-1E in combination with PI-27E are underlain by a confining layer which varies locally in thickness and may contain sand layers with offsite continuity. These sand layers may act as pathways for offsite contaminant migration. LF-1E also appears to be the most constrained geotechnically, and is only able to accommodate landfill designs for which excavations are limited to 5 m.

Siting option LF-4N/PI-1N is the least preferred of the options because of the relatively thin confining layer underlying these sites. Contaminant breakthrough is anticipated to be relatively rapid in comparison to that of the other options. LF-4N is also not able to accommodate the shallow entombed landfill design alternative. Excavations of necessary depth for this alternative would locally intersect the underlying aquifer.

RECOMMENDATIONS

A number of more detailed hydrogeologic assessments will be required during Phase 4B on the preferred site(s) and site(s) vicinity.

- A hydrogeologic assessment should be carried out along the regional and local access routes. This assessment should inventory ground water use and identify the sensitivity of this use to potential spills. The purpose of this assessment would be to serve as a guide for mitigating potential spills.

- A hydrogeologic assessment should be undertaken on and in the proximity of the preferred site(s). The purpose of this assessment would be to confirm the site setting as predicted in this report. In addition, hydrogeologic parameters would be provided to the design engineers to ensure that the conceptual site design and operations is compatible with the hydrogeologic setting.

- A geotechnical assessment should be undertaken to assist in the conceptual foundation design of the various facilities. In this regard, liaison with the design engineers will be required. This assessment should be integrated with the hydrogeologic studies to optimize use of field and laboratory testing.

- A ground water monitoring program should be formulated to serve as an early warning mechanism in the event of unpredicted contaminant movement.

- Contingency plans should be formulated, in conjunction with the design engineers, to act as backup in the event that the monitoring system identifies a need.

STUDY TEAM

This study was carried out under the direction of Grant Anderson, Project Director, Gartner Lee Associates Limited (GLAL). The study team included:

Project Management - Gunther Funk

Geologic Interpretation - Andrew Cooper

Drilling Coordination - Norbert Woerns

Hydrogeologic Interpretation - Kenneth Goff

Geotechnical Interpretation - Douglas Jagger

Hydrogeologic Modelling - Steven Hollingshead

- Edward Sudicky*

* Dr. E.A. Sudicky, of the Ground Water Research Institute, University of Waterloo, acted as advisor to the study team on issues relating to hydrogeologic modelling.

1.0 INTRODUCTION

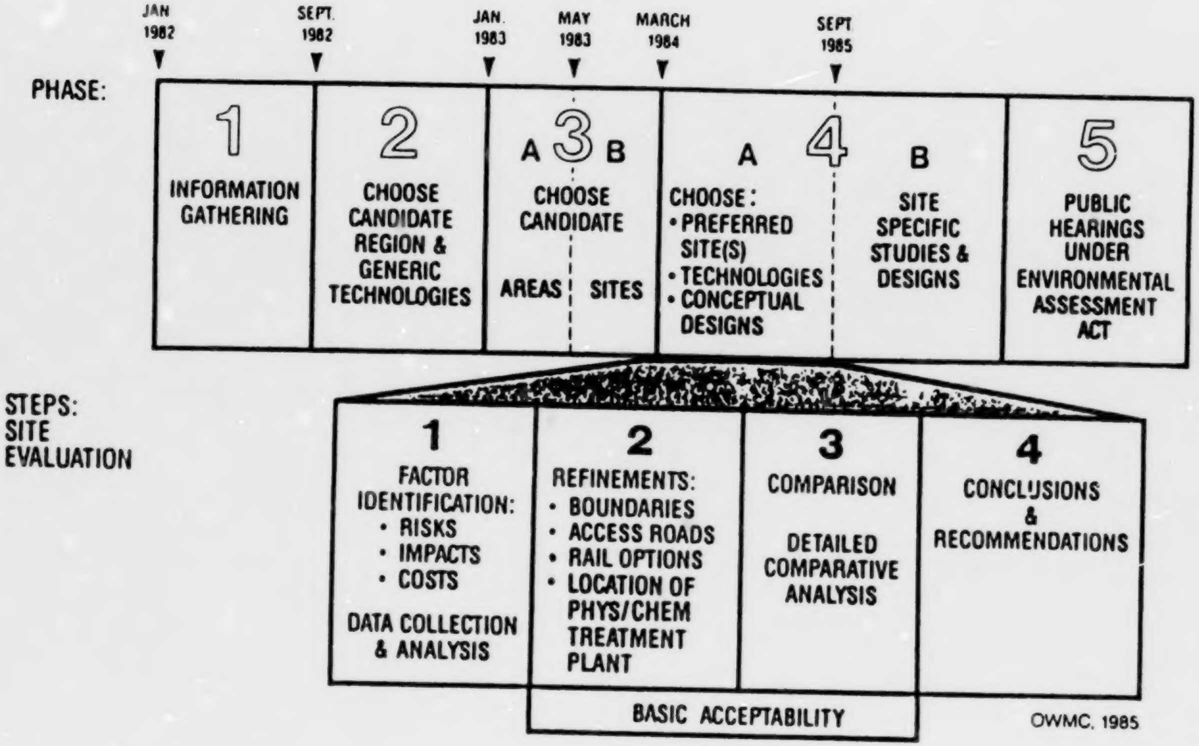
1.1 BACKGROUND

Ontario Waste Management Corporation (OWMC) has implemented a multiphased "Facilities Development Process" to establish facilities for the treatment and disposal of liquid industrial and hazardous wastes ("special wastes") in the Province (Figure 1). The search for an environmentally safe location(s) for the facilities is an important component of the overall process.

The site selection component of the Facilities Development Process has been divided into five separate phases (Figure 1). The first phase (Phase 1) involved the collection of information for a number of different disciplines including hydrogeology. Phase 2, documented in the OWMC report titled Facilities Development Process, Phase 2 Report (1983a) resulted in the identification of a candidate region. Phase 3, which involved the identification of candidate areas and subsequently the eight candidate sites is documented in the OWMC reports titled Facilities Development Process, Phase 3 Interim Report and Facilities Development Process, Phase 3 Report (OWMC, 1983b; 1984). Phase 4A, which involves the evaluation of candidate sites and Phase 4B, which will involve the evaluation of a preferred site(s), will be documented in OWMC's Phase 4 reports, Phase 5 will involve public hearings.

This report describes the role of the geologic, hydrogeologic, and geotechnical consultant, Gartner Lee Associates

FIGURE 1 FACILITIES DEVELOPMENT PROCESS
Phase 4A : Selection of a preferred site(s)



OWMC, 1985

Limited, in Phase 4A - Evaluation of Candidate Sites and Selection of a Preferred Site(s). The candidate sites under consideration during Phase 4A are shown in Figure 2.

It should be stressed that geology/hydrogeology is only one of a number of disciplines used to narrow the geographic focus to a preferred site(s). For an understanding of the role of the other factors, the reader should refer to individual technical reports, prepared during this and previous phases of the process. A detailed discussion of Phase 4A of the site selection process is provided in the report titled Site Selection Process, Phase 4A: Selection of a Preferred Site(s) - Site Selection (M.M. Dillon Limited, 1985).

1.2 PURPOSE AND SCOPE

1.2.1 PURPOSE

Geologic, hydrogeologic, and geotechnical studies were undertaken by Gartner Lee Associates Limited in support of OWMC's site selection process (also identified as Phase 4A: Selection of a Preferred Site(s)). This report and accompanying appendices provide:

- the technical data base developed for the eight candidate sites during Phase 3B and Phase 4A;

- the documentation of the methodology employed in Phase 4A namely the comparative evaluation of the geologic, hydrogeologic, and geotechnical settings of the eight candidate sites; and

- the ranking of the siting options and the rationale for

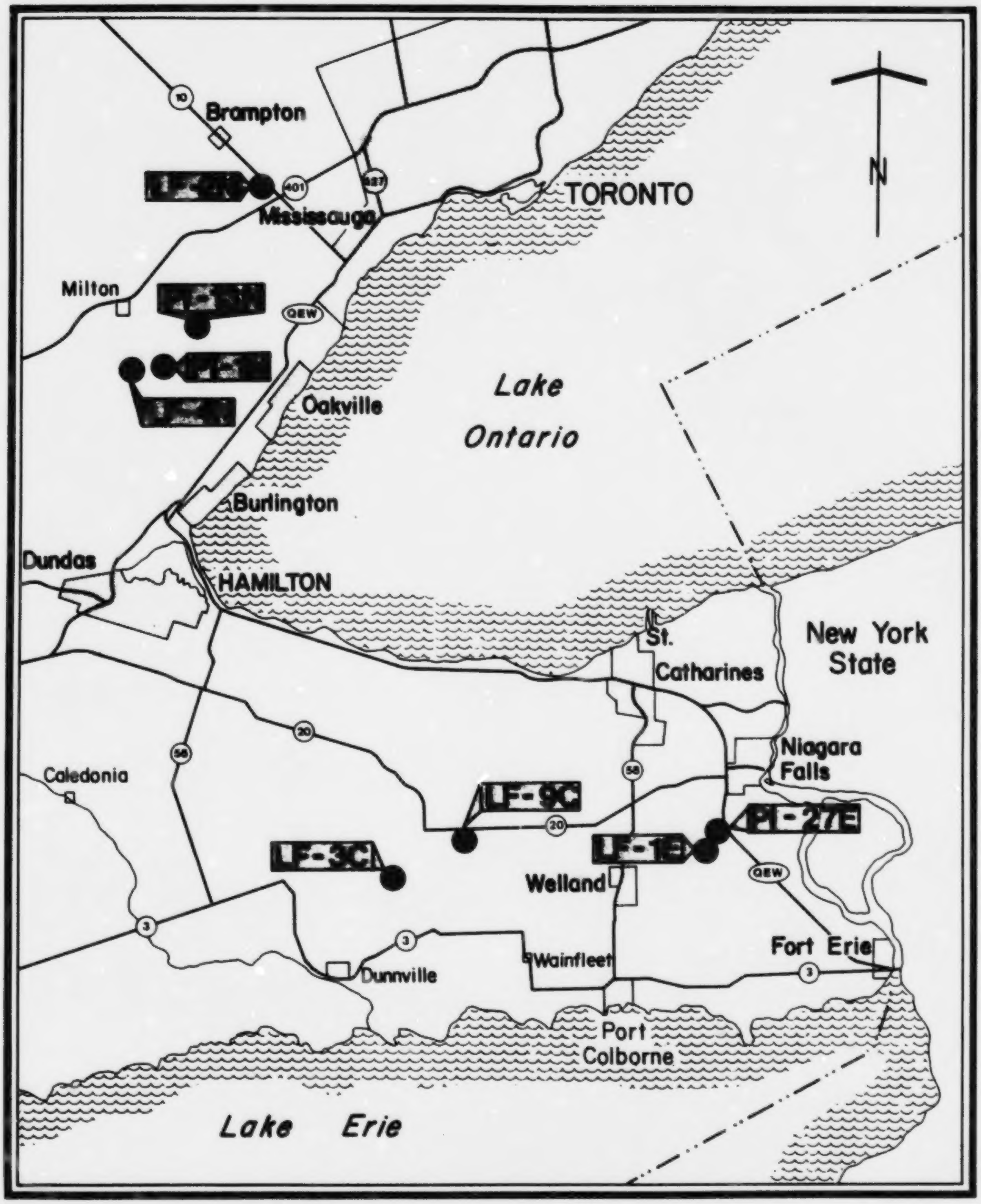


FIGURE 2 LOCATION OF CANDIDATE SITES

the identification of a preferred site(s) during Phase 4A based on geologic/ hydrogeologic, and geotechnical considerations.

1.2.2 SCOPE OF EARLIER GEOLOGIC/HYDROGEOLOGIC STUDIES (PHASES 1 TO 3)

Figure 3 summarizes the role of geology and hydrogeology during the first three phases (Phase 1, Phase 2, and Phase 3) of the site selection process. Decisions on the geologic/ hydrogeologic suitability of the increasingly smaller sized geographic study areas were guided by OWMC's general principles of site selection.

These principles, and the various goals and objectives developed as the process evolved, resulted in a methodology during these phases which essentially involved:

- the analysis of the geologic/hydrogeologic setting of the area under consideration, at progressively larger scales (1:250,000 - Phase 1 and Phase 2, 1:50,000 - Phase 3A and 1:10,000 - Phase 3B);

- The division of the study area into smaller land areas based on geologic features or conditions, with the boundaries of each land area roughly corresponding to the maximum areal extent of the identified feature;

- the grouping of the smaller land areas in accordance with each area's potential to provide for the natural containment of contaminants (i.e. containment without reliance on engineered systems);

FIGURE 3 SITE SELECTION PROCESS -
GEOLOGIC/HYDROGEOLOGIC ROLE

PHASE 1 and PHASE 2: NARROW THE SEARCH TO A GEOGRAPHIC REGION IN ONTARIO

Major Activities Undertaken	Results and Recommendations	Reports
• major geologic/hydrogeologic features of southern Ontario identified, mapped (scale of 1:250,000) and described.	• a total of 261 regions were delineated and grouped into 6 hydrogeologic zones. • zone 1 and 2 lands may naturally restrict potential contaminant movement	GLAL 1982a 1982b

OWMC decision to focus future study on Zone 1 and 2 lands within the Golden Horseshoe (OWMC 1982, 1983a).

PHASE 3A: IDENTIFY CANDIDATE AREAS SUITABLE FOR EACH FACILITY COMPONENT WITHIN THE GOLDEN HORSESHOE

Major Activities Undertaken	Results and Recommendations	Reports
• documentation of hydrogeologic considerations in facility siting to provide guidance for the selection of priority areas of study	• areas underlain by the deepest, most consistent fine textured soils be given the highest priority of study. • for an engineered landfill, areas of less than about 10 m of fine textured soils should not be considered and a higher degree of confidence would be realized as soil thickness increases. • for a treatment facility and incinerator areas underlain by less than about 10 m of fine textured soils could be considered but more detailed site investigation would be required.	GLAL 1983
• desk top analysis of the geology/hydrogeology of Zone 1 and 2 lands of the Golden Horseshoe at a scale of 1:50,000	• a total of 25 "Geologic Areas" and 65 smaller subareas were identified and grouped into a 4 category classification system • category 1 and 2 lands were assigned the highest priority for future study	GLAL 1984a

OWMC decision to study only Category 1 and 2 lands. The search for an engineered landfill or fully integrated facility was to focus in areas underlain by at least 20 m of fine textured soils and for a physical chemical plant and incinerator in areas underlain by at least 10 m of such soils. A total of 20 candidate areas were identified. (OWMC 1983b)

PHASE 3B: IDENTIFY CANDIDATE SITES WITHIN CANDIDATE AREAS

Major Activities Undertaken	Results and Recommendations	Reports
• preliminary analysis of geology, hydrogeology, surface drainage and physical terrain conditions • preparation of physical resource maps (constraint maps) at a scale of 1:50,000 • progressive refinement of data base for 90 site areas and 16 potential sites at a scale of 1:10,000	• identification of 10 physical resource factors and recommendation that portions of candidate areas containing 'surface granular soil', 'stream course', 'flood plain', 'wetland', 'drumlin (Niagara)', 'drumlin field' and moraine be considered as exclusionary. • 38 site areas may potentially be considered for an integrated facility or landfill (12 ranked as 'Level 1', 14 ranked as 'Level 2' 12 ranked as 'Level 3'. • 52 site areas may potentially be considered for a chemical treatment plant or incinerator (16 ranked as 'Level 1', 27 ranked as 'Level 2', 9 ranked as 'Level 3'. • portions of site areas containing constraints (flood plains, stream courses, spoil piles and moraines) should be considered exclusionary for facility placement. • of the 17 siting options (includes the 16 potential sites) 2 were ranked as 'Level 1', 5 as 'Level 2' and 9 as 'Level 3'. • Only one site LF-3E was ranked as 'major constraint' and should be excluded based on hydrogeology.	GLAL 1984b

OWMC accepted the site selection team's recommendation to focus future study on the eight candidate sites which were identified (OWMC 1984 and Dillon 1984).

- the ranking of the grouped areas during Phase 1 and Phase 3A into Hydrogeologic Zones, and Category Lands, respectively; and
- the comparison of site areas and potential sites during Phase 3B to identify candidate sites.

1.2.3 SCOPE OF THIS STUDY (PHASE 4A)

Phase 4A of the site selection process has four steps (Figure 1).

The first step involved the identification of site selection factors which could be used in evaluating differences and similarities in the potential risks, impacts and costs of the proposed facilities among the eight candidate sites. These factors were grouped into three categories, related to the following in order of priority:

(1) risk to human health;
(2) environmental impacts;
(3) cost.

The hydrogeologic factors used in this study are grouped in the 'risk to human health' category.

The second step involved refinement of the siting options. During this step, site boundaries were refined (for three of the sites), various alternative road and rail access options were compared to identify preferred options, and preferred locations for the physical/chemical treatment plant were established.

The third step involved the comparison of the siting options. This step included an evaluation of the individual sites to establish their basic acceptability. The basic acceptability analysis involved the identification of major constraints as a result of new information collected during Phase 4A studies, which could preclude the use of a site. From a hydrogeologic perspective, the failure of a site to provide natural containment of potential contaminants is viewed as a major constraint to facility development. Where such containment is identified as being potentially non-existent, the site is not anticipated to be capable of providing the second level of protection of the environment desired by OWMC. The final comparison of siting options is limited to those sites and combinations of sites which basically are acceptable.

The fourth and final step involved, a) the final ranking of factors and siting options, b) the documentation of site specific conditions, and c) the presentation of recommendations for Phase 4B.

All information and analysis (interpretive mapping, matrices and options comparison tables) presented in this report and the companion technical appendices, were provided to the site selection coordinating consultant (M.M. Dillon Limited) and the engineering consultant (Monenco Limited). This information, along with similar contributions from consultants in other disciplines, was utilized by the site selection team to select preferred options at each stage in the process. The overall process is documented in the Phase 4A report titled Site Selection Process, Phase 4A: Selection of Preferred Site(s) - Site Selection (M.M.Dillon Limited, 1985a).

The engineering consultant utilized the geologic/hydrogeologic and basic geotechnical information presented in the technical appendices and in Appendix A of this report, in the preliminary design of facilities and in the analysis of costs and site operational capacities. This information is presented in the engineering report titled Site Selection Process, Phase 4A: Selection of a Preferred Site(s) - Engineering (Monenco Limited, 1985b).

1.3 APPROACH

The general approach followed during Step 4 (Phase 4A) of the process including the identification of siting options and alternatives within each option and the overall site selection procedures, was formulated by the site selection coordinating consultant (M.M. Dillon Limited) in consultation with the individual technical consultants. Identification of the appropriate scope and scale of the study, the approach to data collection and analysis, and the procedures employed to compare and rank options were established by the individual technical consultants in consultation with M.M. Dillon Limited and OWMC staff.

The OWMC site selection process is guided by three goals, which in order of importance are to:

(1) minimize risk to human health;
(2) minimize environmental impacts; and
(3) minimize financial costs to OWMC and the people of Ontario.

The hydrogeologic analysis was related primarily to the minimizing of risk to human health. To accommodate this goal it is necessary to have an appreciation of:

- the 'source' of potential risks to human health and the environment namely potentially hazardous contaminants which could be released from OWMC's proposed facility;
- potential 'pathways' along which contaminants may move from the facility to the 'receptors'; and
- the potential for human exposure through the consumption of well water supplies or surface water.

Characteristics of the proposed facility and potential sources of contamination are summarized in Section 1.4. The link to human health stems from the possibility of contaminants moving from the facilities through the subsurface into underlying local aquifers used for water supply purposes (Figure 4). Similarly, contaminants may follow ground water flow paths and discharge to local surface water courses, resulting in an effect on both human health (via swimming, drinking etc.) and the environment (i.e. aquatic life). It was initially suggested that, if the types, fluxes and concentrations of contaminants discharging to local aquifers from the facilities could be quantified, then this information could be provided to the risk assessment consultant (Environ, Inc.) for an approximate quantification of hydrogeologic risks. This type of risk assessment would estimate statistically, the probability of injury, disease, or death

FIGURE 4 GROUND WATER PATHWAYS AND WATER USE

Source of Potential Contaminants	● LANDFILL ● INCINERATION AND PHYSICAL/CHEMICAL TREATMENT PLANTS (CENTRAL OPERATING AREA) ● WASTE TRANSPORTATION
Ground Water Pathways	● LATERAL MOVEMENT THROUGH SHALLOW FRACTURE ZONE OF CONFINING LAYER ● DOWNWARD MOVEMENT THROUGH CONFINING LAYER ● MOVEMENT ALONG MAN-MADE PATHWAYS ● VARIOUS GEOLOGIC MATERIALS AT SITE OF ACCIDENTAL SPILLS DURING WASTE TRANSPORTATION
Water Use	● GROUND WATER ● SURFACE WATER

occurring under specific conditions of exposure to toxic and hazardous contaminants. The various siting options would then be compared using the risk statistics generated by Environ, Inc. However, because the type and quantity of potential emissions to ground water cannot be established at this time to the level of detail required for input to risk assessment (Section 1.4), the focus of the hydrogeologic analysis has been on a qualitative comparison of siting options.

The qualitative comparison of the siting options has involved the identification and characterization of potential hydrogeologic pathways. In general, there are two ground water pathways by which contaminants can potentially leave any site; these are (a) natural pathways along ground water flow systems and (b) man-made pathways which follow subsurface structures such as abandoned and unplugged wells and tile drains. Preference is given to those sites where the natural pathways are expected to retard ground water and contaminant movement. With respect to man-made pathways, remedial measures are available which can mitigate the risks associated with these pathways following their identification on site.

Considerations specific to surface water are addressed in the report titled Site Selection Process, Phase 4A: Selection of a Preferred Site(s) - Surface Water Considerations. (Gartner Lee Associates Limited, 1985).

Information on site specific geotechnical considerations was provided to the engineering consultant, Monenco Limited and was used as input to their analysis of cost and site landfilling capacity. As such, the geotechnical considerations are not dealt with extensively in this report as they were not used by Gartner Lee Associates Limited to assist in the hydrogeologic comparison of sites. Geotechnical considerations are outlined in the technical appendix for each site. The reader should refer to the Monenco Limited engineering report titled Site Selection Process, Phase 4A: Selection of a Preferred Site(s) - Engineering (Monenco Limited, 1985b) for detailed information on how the geotechnical information was used.

As is shown in Figure 1 the Phase 4A methodology included:

- the identification of site selection factors which could be used in the collection of field data and in the identification of potential risks associated with facility development and operation;
- the collection, compilation, and analysis of geologic, hydrogeologic, and geotechnical data to describe existing site conditions;
- the refinement and comparison of siting options through the application of the factors.

Factors used in the refinement and comparison of the siting options are listed in Table 1 and are defined in the factor sheets presented in Appendix B. A detailed discussion of the factors is contained in Sections 2 and 3 of this report.

Various study areas identified in Table 1 were chosen for

TABLE 1

FACTORS USED IN THE REFINEMENT AND COMPARISON OF SITING OPTIONS

FACTOR	Study Area			Refinement Of Siting Options		Basic Acceptability Of Siting Options	Comparison Of Siting Options	Time Frame		
	Rail Access And Access Roads	Site	Site Vicinity	Rail Access And Access Road Options	Refinement Of Site Boundaries			Pre Operational	Operational	Post Closure
Distance through Hydrogeologically Sensitive Lands	x			x			x		x	
Confining Layer Thickness		x			x			x		
Capability of Providing Natural Containment		x	x			x	x		x	x
Impact on Ground Water Use			x				x		x	x

purposes of collecting information on the factors. The 'site' refers to the study area identified as the candidate site (OWMC, 1984). The 'site vicinity' refers to a study area extending approximately 2 km outwards from the centre of the site. By extending the area of study beyond the site it is possible to:

- supplement onsite data with additional offsite data;
- demonstrate that onsite geologic trends have predictability and uniformity beyond the site boundaries; and
- identify geologic anomalies or offsite features which could affect the interpretation of local conditions.

Because water wells, a significant source of information, are usually located along roadways, a 2 km study area generally extends a sufficient distance to include adjacent concession roads. Geologic anomalies and features beyond this radius are not expected to influence the interpretation of site conditions.

'Access roads' study area includes both local and regional access routes and associated impact zones and the 'rail access' study area includes the various route options and associated impact zones considered for rail service.

The time frame over which the factors apply are also identified in Table 1. 'Pre-operational' refers to considerations leading up to facility placement (i.e. siting preference for siting facilities on lands underlain by the thickest, fine-textured soils). 'Operational' and 'Post Closure' refer to considerations resulting from the potential release of contaminants during facility operations, and over the long-term following facility closure, respectively.

1.4 FACILITY CHARACTERISTICS

The comparison of siting options is predicated on an appreciation of how and what contaminants may come in contact with the hydrogeologic environment. It is therefore necessary to have as complete a description of the proposed undertaking as possible. By definition, each siting option includes:

- either a single site (fully integrated), where all facility components are located at the same site, or separate sites (partially integrated) for the landfill, and incineration and physical/chemical treatment plants; and

- access roads both to the site(s) from 400 series highways and between sites for intersite transfers; and

- rail access options for transport of additives and reagents (rail service is viewed as an opportunity rather than an absolute requirement).

Site boundaries were established as a result of the Phase 3B analysis described in OWMC's report titled

Facilities Development Process, Phase 3B Report. (OWMC, 1984). Access road options were identified by the transportation consultant, M.M. Dillon Limited, both during Phase 3B and during Phase 4A. Rail access options were identified by M.M. Dillon in consultation the site selection team through a constraint mapping exercise during Phase 4A.

A brief discussion of the major facility components, type of wastes handled at each facility, and potential sources of contaminants at the facility are provided below. A more complete description of the proposed facilities is provided in the report titled Status Report, Facility Design (Monenco Limited 1985a). In addition, site layouts showing locations of the various facility components proposed for each site are presented in the report titled Site Selection Process, Phase 4A: Selection of a Preferred Selection of a Preferred Site(s) - Engineering (Monenco Limited, 1985b).

1.4.1 ENGINEERED LANDFILL

Solidified materials from the treatment processes are intentionally and permanently placed in the landfill. For purposes of this comparison of siting options, it has been assumed that the engineered landfill will consist of a number of separate cells or trenches adapted to the conventional design. Solidiified mass will be placed in excavations extending to 10 m in depth and filling will continue to form a mound to 12 m in height. A minimum 50 m buffer zone will be left between the cell development area and the acquisition boundary.

Two additional landfill design alternatives are also under active consideration. These are:

- Above-ground landfill which is completed fully above ground surface; and

- Shallow entombed landfill which is completed fully below ground surface.

A brief description of these alternative landfill designs is provided in Section 3.6. The reader should refer to the report titled Status Report, Facility Design (Monenco Limited, 1985a) for a more detailed description of these alternatives.

Any landfill design concept will likely include the following:

- installation of a leachate control system in initial cells which would be activated to provide information on leachate generation and leachate quality;

- installation of a cover system to minimize infiltration;

- installation of surface drainage controls;

- installation of ground water and surface water monitoring networks and the development of contingency plans which would be activated as required by monitoring; and

- development of closure and long term maintenance (post closure) plans.

The landfill will accept treated residues which will be primarily inorganic in nature. No liquids or untreated wastes will be landfilled. According to Monenco Limited (1985a), these waste residues will include:

- residues from physical/chemical treatment that have been processed in the solidification plant;
- incinerator slag;
- residues from the incineration plant that have been processed in the solidification plant; and
- solidified inorganic wastes, the physical and chemical characteristics of which do not require other treatment prior to solidification.

The solidified mass will be physically stable and will not revert back to its original liquid or sludge state (Monenco Limited, 1985a).

These residues and slags are to be combined in the landfill to form what is referred to in the Status Report, Facility Design (Monenco Limited, 1985a), as 'solidified mass'. The reader should refer to this report for a discussion of the characteristics of: (a) the solidified mass; (b) contaminants expected to be contained in the solidified mass; and (c)leachate expected to be produced as a result of contact between infiltrating water and the solidified mass.

Although the actual concentration of leachate constituents is not expected to be known until the facility is operational, preliminary indications are that the leachate will not exceed Ontario Drinking Water Objectives for most constituents (Monenco Limited, 1985a).

However, the hydrogeologic site comparison incorporates a conservative ('worst case') approach to contaminant release. Because leachate characteristics cannot be fully anticipated, it has been assumed that the leachate could contain trace quantities of organic and inorganic contaminants which could represent a health and/or environmental concern. It is also assumed that leachate will be produced and start to migrate from the base of the landfill from the initial start up of the facility. The leachate will be sampled and tested to establish characteristics.

1.4.2 CENTRAL OPERATING AREA

Facilities in the central operating area include a physical/chemical treatment plant, a rotary kiln incineration plant, and a solidification plant. Unlike the landfill, wastes will be handled, stored and treated at these facilities for only a finite length of time. This time will be governed by the active life of the facility.

Treatment components and handling methods will be compatible with the waste streams and will be designed to minimize environmental exposure. Quality and quantity control, supervision and monitoring will verify the composition of the waste loads received. From this it will be possible to determine the appropriate treatment processes and control the quality of the processing. Site specific spill containment features would include pads, berms, and drainage collection installations (Monenco Limited, 1985a, 1985b).

The central operating area will handle and treat a wide range of wastes consisting primarily of heavy metal solutions and residuals. Oil/water mixtures, organic and oil residuals, and paint residuals are also to be treated at this facility.

The organic compounds, following initial treatments, will be transferred to the rotary kiln incineration plant. The incinerator will handle and burn primarily organic compounds. Following incineration and/or solidification, residues will be transferred to the landfill for disposal.

The solidification plant will mix reagents with waste residues from the treatment plant to produce a solidified material for landfilling.

The central operating area will contain waste handling and storage facilities which include storage tanks of various sizes for liquid wastes, bunkers for solids, and transfer piping. Each site will also include surface drainage controls which collect uncontaminated runoff from building roofs and grassed areas, and potentially contaminated runoff from the roads. The uncontaminated and potentially contaminated drainage waters will be directed to separate detention ponds.

Monenco Limited (1985b) has compiled a list of potential events which could result in spills or leaks. Representative examples of these events have been used in this study to evaluate the natural capacity of each site to contain potential contaminants. These representative contaminant release examples include:

- An onsite spill scenario which assumes that a contaminant residual would remain after the cleanup of a major spill event. An example of such an event is a tanker truck overturning and resulting in the spillage of its contents. The contaminated residual is assumed to be at surface or within a few metres of surface in an area which cannot be readily accessed until such time as the facility is decommissioned.

- A subsurface leakage scenario which assumes that a leak occurs from an unloading tank or sump located below the ground surface. For purposes of comparison, the leak is assumed to occur from a structure 8 m below the ground surface. Caissons and piles may extend to greater depths; however, these can be effectively sealed into the soil and therefore are not considered as potential contaminant source pathways. Minor leaks could occur from several sources at the plant facility and potentially remain undetected over the life of the facility.

It has been assumed for both examples that untreated wastes, which represent a health and/or environmental concern, are released.

1.5 REPORT FORMAT

The Phase 4A geologic, hydrogeologic, and geotechnical study results are contained within a nine volume set. This report documents:

- the role of the hydrogeologic consultant in the site selection process;

- the methodology employed in the comparative evaluation of the siting options, and
- the results of the comparative evaluation.

Appendix A in this report provides a detailed assessment of contaminant transport through the confining layer present at each site.

Eight separately bound technical appendices describe the geologic, hydrogeologic, and geotechnical setting at the eight candidate sites. These appendices contain:

- the extensive data base collected during this and earlier phases of the study; and
- general geotechnical information for the engineering consultant.

2.0 REFINEMENT OF SITING OPTIONS

2.1 INTRODUCTION

This section describes the role of the hydrogeologic consultant in the refinement of the siting options to facilitate their evaluation and comparison. These refinements included:

- refinement of the site acquisition boundaries for three sites - LF-1E, LF-3C and PI-1N, (Section 2.2);
- comparison of access road options to identify preferred access roads for each siting option, (Section 2.3);
- comparison of rail access options to establish links to existing main railway lines, (Section 2.4); and
- comparison of partially integrated siting options to determine the location of the physical/chemical treatment plant on either the landfill sites or the incinerator sites.

The hydrogeologic factors shown in Table 1 were used in the above refinements for the three sites (Section 2.2) and to the identification of preferred access road options (Section 2.3) and preferred rail access options (Section 2.4).

As noted in the report titled Site Selection Process, Phase 4A: Selection of a Preferred Site(s) - Site Selection (M.M. Dillon Limited, 1985a), rail service to the sites was considered to be an opportunity which would be realized only if this service offered significant advantages over road access.

Hydrogeology was not considered in the identification of preferred locations for the physical/chemical treatment plant (either on the landfill sites or on the incinerator sites). A comparative analysis of the options (i.e. location of the physical/chemical treatment plant with the landfill or with the incineration plant) would require a thorough understanding of the significance of introducing additional potential contaminants to the hydrogeologic setting. As previously discussed in Section 1.4 because the composition, toxicity and quantities of contaminants which could potentially be released from the facilities cannot be fully anticipated, it is not possible to assess, in absolute terms, the risk to human health and the environment posed by such releases. For this reason, the comparison of the siting options was based on the assumption that all releases of contaminants pose some risk, irrespective of their magnitude (volume and toxicity).

2.2 REFINEMENT OF SITE BOUNDARIES

Three of the candidate sites -- LF-1E, LF-3C and PI-1N, as delineated by OWMC during Phase 3B, were initially considered to be larger in size than would ultimately be required for facility development. In order to minimize the disruption to existing land use, the site selection team evaluated the sites with the intent of reducing them in size. The sites were screened by the site selection team using multidisciplinary factors to identify general preferences for facility arrangement.

The role of geology and hydrogeology in the refinement of site boundaries is described in the following sections.

2.2.1 FACTOR IDENTIFICATION

Geologic, hydrogeologic, and preliminary geotechnical information has been collected for each of the candidate sites to facilitate the comparison of siting options. While the data collection program was not specifically designed to accommodate detailed 'onsite' comparison or to identify constraint features or conditions on individual sites, certain generalizations could be made respecting the preferential development on select portions of the sites. Consequently, factors were not specifically identified for this task at the onset of the data collection program, but rather were identified following review of the accumulated information base.

To accommodate this analysis, emphasis was placed on identifying one or more factors which were likely to vary across the site and therefore would be useful for onsite comparison. Based on an examination of onsite geologic information (technical appendices) it became apparent that the total thickness of fine textured materials, also known as the confining layer thickness, varies both between sites and in some cases between borehole locations on the same site. The confining layer thickness could therefore be used as a factor for onsite comparison. Confining layer thickness is a general indicator of an area's ability to provide natural containment of contaminants and was initially used as a factor to compare potential sites during Phase 3B. As the thickness of the confining layer increases, the length of time for contaminants to reach underlying more permeable materials also increases. Information on confining layer thicknesses is included in the technical appendices prepared for each of the candidate sites.

For the purposes of this evaluation, preference is given to siting facilities over those portions of the site where the confining layer is thickest.

2.2.2 FACTOR APPLICATION

Figures 5, 6 and 7 are confining layer thickness maps for LF-1E, LF-3C and PI-1N, respectively. The thickness zones are depicted in 10 m intervals.

The confining layer thickness below LF-1E (Figure 5), as identified from Gartner Lee Associates Limited boreholes (GL1 through GL5), ranges from 9.0 m (GL5) in the south to 27.1 m (GL2) along the northeastern edge. Sand and gravel, attributed to a morainal feature, were encountered at surface at Borehole GL6. Thus, there is no confining layer protecting the aquifer at this location. These granular materials extend to depth and there is some suggestion that sand lenses may extend laterally (westward) under the site.

A series of boreholes completed by the St. Lawrence Seaway Authority (SLSA 1220 through SLSA 1227) along a rail alignment immediately west of the site are also included. It should be noted however, that the SLSA boreholes were completed to obtain geotechnical data for the purpose of constructing the rail line, and they frequently did not completely penetrate the confining layer. Preference should

FIGURE 5 CONFINING LAYER THICKNESS AT LF-IE

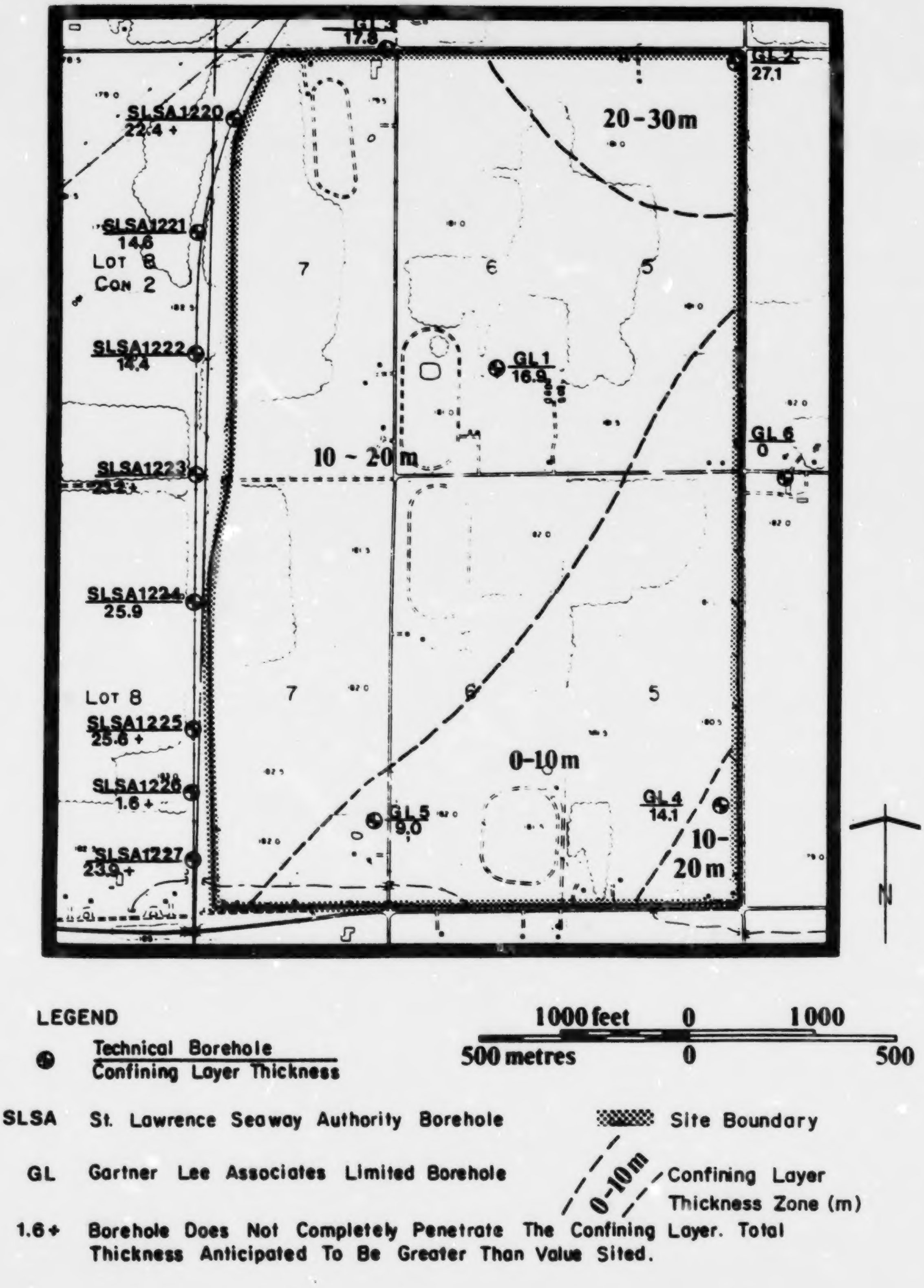

GL 3
17.8
GL 2
27.1
SLSA1220
22.4 +
20-30m
SLSA1221
14.6
Lot 8
Con 2
7
6
5
SLSA1222
14.4
GL 1
16.9
GL 6
0
10 ~ 20 m
SLSA1223
23.2 +
SLSA1224
25.9
Lot 8
7
6
5
SLSA1225
25.6 +
0-10m
SLSA1226
1.6 +
GL 5
9.0
GL 4
14.1
10-
20m
SLSA1227
23.9 +
N
1000 feet
0
1000
500 metres
0
500
LEGEND
Technical Borehole
Confining Layer Thickness
SLSA St. Lawrence Seaway Authority Borehole
GL Gartner Lee Associates Limited Borehole
Site Boundary
0-10m
Confining Layer Thickness Zone (m)
1.6+ Borehole Does Not Completely Penetrate The Confining Layer. Total Thickness Anticipated To Be Greater Than Value Sited.

FIGURE 6 CONFINING LAYER THICKNESS AT LF-3C

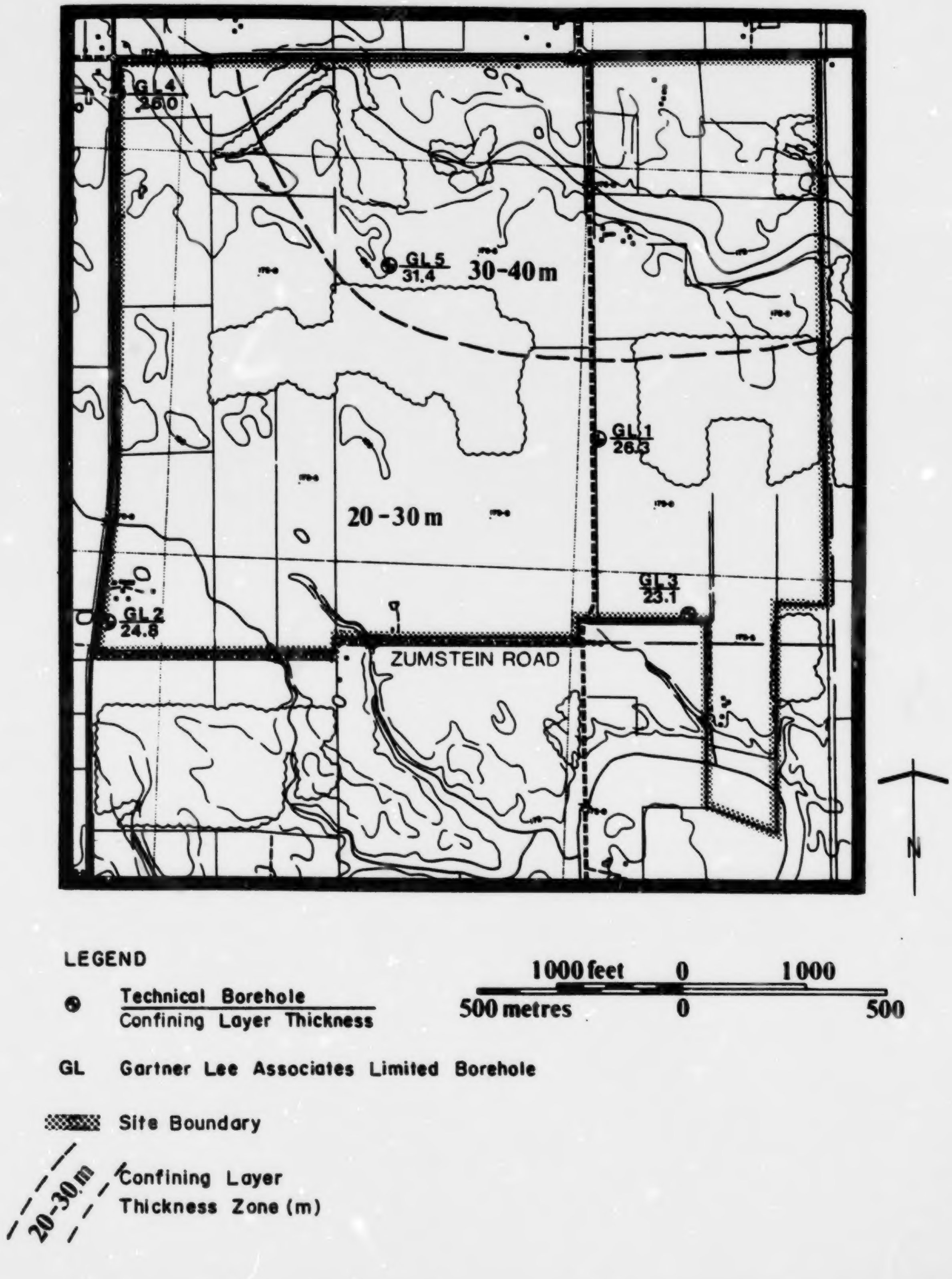
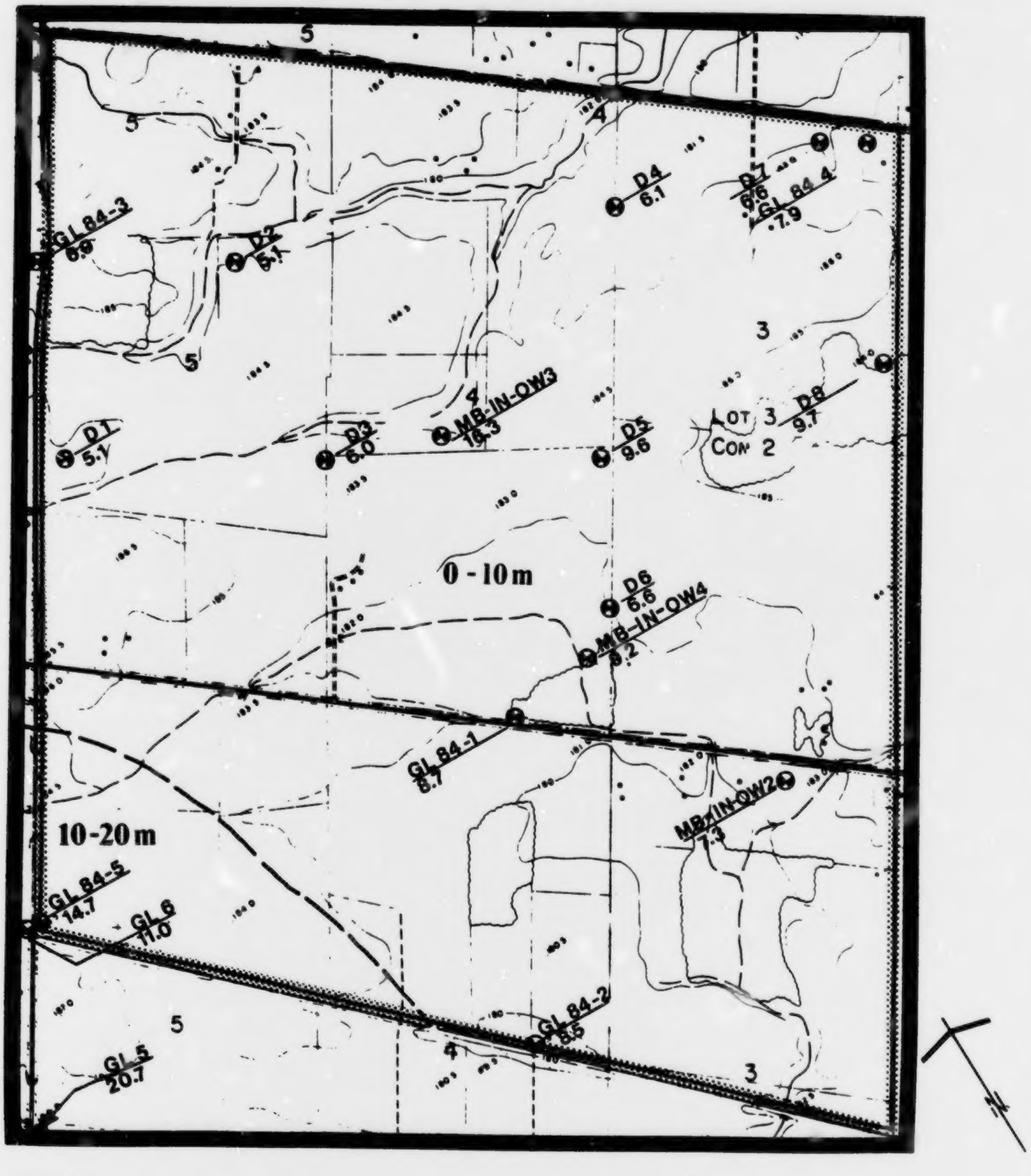


FIGURE 7 CONFINING LAYER THICKNESS AT PI-IN



LEGEND

1000 feet 0 1000
500 metres 0 500

⊕	Technical Borehole / Confining Layer Thickness
GL84-1	Gartner Lee Associates Limited Borehole Completed At PI-IN (1984)
GL	Gartner Lee Associates Limited Borehole (1976-1979)
D1	Hydrology Consultants Limited Borehole
MB-1N-OW3	Morrison Beatty Limited Borehole
▨	Site Boundary
0-10m	Confining Layer Thickness Zone (m)

be given to siting facilities over those portions of the site where the confining layer is greater than 10 m thick to optimize natural contaminant containment capability.

The confining layer thickness below LF-3C (Figure 6) ranges from 23.1 m (GL3) to 31.4 m (GL5). Based strictly on the confining layer thickness, no clear preference for facility siting is evident.

At PI-1N, boreholes (D1 through D8), completed by Hydrology Consultants Limited for the Regional Municipality of Halton, and boreholes (MB-1N-OW2 through MB-1N-OW4) completed by Morrison Beatty Limited for the Town of Milton, are included to facilitate interpretation. Confining layer thickness ranges from 5.1 m (D1 and D2) to 16.3 m (MB-1N-OW3) and averages between 6 and 9 m. Again, no clear preference for facility siting is evident based strictly on the confining layer thickness.

Revised boundaries for LF-1E, LF-3C and PI-1N, as defined by the site selection team using multidisciplinary factors, are presented in Figures C1, C2 and C3, Appendix C. A discussion of the process used in refinement of the boundaries is presented in the report titled Background Material for the OWMC Phase 4A Site Selection Workshop, Volume 1 (OWMC 1985) and in the M.M. Dillon Limited (1985a) site selection report.

2.3 ACCESS ROAD OPTIONS

A number of alternative access roads to and between the various candidate sites were carried forward to Phase 4A from Phase 3B. In addition, other roads were identified by the transportation consultant (M.M. Dillon Limited) during the earlier portion of Phase 4A. The various access road options are shown in Figures C4 to C15, Appendix C. In order to reduce the number of alternative access road options to each site, the site selection consultants were required to conduct a further analysis during Phase 4A, of the options. It should be noted that this analysis was limited only to those access roads for which options were available. In some instances, only one access route was carried forward from Phase 3B or else the preferred access route had been identified during Phase 3B. The analysis of these routes was not undertaken. The Phase 4A analysis was conducted at two levels of detail:

- a preliminary evaluation of options using access road factors employed in Phase 3B, and
- a second (more detailed) level of analysis of access road options, involving a wider range of factors.

Hydrogeologic input was limited to the first level of analysis presented above. The second (more detailed) analysis was not considered appropriate because of the potential for mitigating transportation spills.

2.3.1 FACTOR IDENTIFICATION

The hydrogeologic factor identified during Phase 3B to address concerns arising from an accidental spillage of waste during transport was considered appropriate for this preliminary evaluation of access road options. This factor encompasses considerations specific to geologic conditions which may exist along some access roads that could allow for the subsurface migration of liquid waste from the spill site.

It should be recognized that because such spills would be attended to promptly, the likelihood of contaminants migrating any distance from the spill site is remote. However, in keeping with the goals developed and adopted by OWMC, namely to minimize risk to human health and the environment, the hydrogeology factor 'Distance Through Hydrogeologically Sensitive Lands' was applied during the preliminary evaluation of options to identify the access road option from the 400 series highways with the shortest distance of sensitive lands. The factor sheet which provides a detailed discussion of this factor is provided in Appendix B.

Sensitive lands are identified as those lands along the access roads which are underlain by permeable geologic materials that could allow subsurface migration of contaminants from the spill site. Sensitive lands are defined as being underlain by:

- bedrock at or near surface;
- granular soil at or near surface;
- floodplain deposits (generally variable texture);
- man-made fill (such as granular backfill material).

2.3.2 FACTOR APPLICATION

The analysis of access road options is based on the distance travelled over sensitive lands between 400 series highways and the candidate sites.

Alternative access roads were identified by the site selection team transportation consultant (M.M. Dillon Limited) on 1:50,000 scale topographic map bases. Information on the surficial geology along the access roads is available from published geology maps and from constraint mapping completed during Phase 3B.

Sensitive lands along these alternative access roads were identified on the topographic map bases. The linear distance of sensitive land that the access roads (both local and regional roads) cross through was measured. The measured lengths for each of the access road options are presented in Table 2. The access road options were next ranked from most preferred to least preferred based on the total length of sensitive land crossed by the road. In other words the access road with the shortest length of sensitive land was ranked first in preference. The relative ranking is also shown in Table 2.

The linear distance of sensitive lands and the ranking of the access road options were provided to the site selection team for inclusion in the comparison of the various access road options.

2.4 RAIL ACCESS OPTIONS

Rail service is viewed as an opportunity for the bulk haulage of process additives and reagents rather than as an absolute requirement of a siting option. The lack of rail service to a site would not necessitate the rejection of the site. Two impact zones (i.e. 170 m and 250 m wide) were identified in the Transportation report titled Site Selection Process, Phase 4A: Selection of a Preferred Site(s) -

Table 2
Page 1 of 3

HYDROGEOLOGIC RANKING OF ACCESS ROAD OPTIONS

SITE	ACCESS ROAD OPTION	SENSITIVE LANDS (m)		HYDRO-GEOLOGICAL RANKING
		Local Roads	Regional Rds.	
A. Integrated Sites				
(i) LF-3C	(1) QEW - RR 24 - Hwy 20 - RR 27 - Elcho Rd.	100	4300	5
	(2) *QEW - RR 18 - RR 69 - RR 569 - Hwy 20 - RR 27 - Elcho Rd.	100	2200	1
	(3) *QEW - RR 14 - RR 714 - RR 73 - RR 14 - RR 16	-	3050	3
	(4) *QEW - RR 18 - RR 69 - Hwy 20 - RR 27 - Elcho Rd.	100	2250	2
	(5) *QEW - RR 24 - Hwy 20 - RR 65 - Smithville Rd.	-	4450	6
	(6) QEW - RR 24 - Hwy 20 - RR 65 - Krick Rd.	-	4300	4+
(ii) LF-9C	(1) QEW - RR 24 - HWY 20	-	4300	3+
	(2) *QEW - RR 18 - RR 69 - RR 569 - Hwy 20	-	2200	1
	(3) *QEW - RR 18 - RR 69 - Hwy 20	-	2250	2
(iii) LF-1E	(1) QEW - RR 47 - Montrose Rd.-Carl Rd.	-	150	2
	(2) *QEW - RR 47 - Morris Rd.	-	-	1
	(3) QEW - RR 47 - Crowland Ave.	-	-	1
	(4) QEW - RR 47 - Montrose Rd. - Young Rd.	-	150	2
	(5) QEW - RR 47 - Montrose Rd. - Schisler Rd.	-	1200	3
	(6) QEW - RR 47 - Crowland Ave. - Carl Rd.	-	-	1+
	(7) QEW - RR 47 - Montrose Rd. - Carl Rd. - Crowland Ave.	-	150	2

*Options eliminated in preliminary Phase 4A screening of access route options
+Preferred Access Road identified by Site Selection Team

Table 2
Page 2 of 3

HYDROGEOLOGIC RANKING OF ACCESS ROAD OPTIONS

SITE	ACCESS ROAD OPTION	SENSITIVE LANDS (m) Local Roads	SENSITIVE LANDS (m) Regional Rds.	HYDRO-GEOLOGICAL RANKING
B. Partially Integrated				
(i) LF/2N/PI-1N to PI-1N	(1) Hwy 401 - Fourth Line - Britannia Rd.	-	250	1+
	(2) *Hwy 401 - Fourth Line - Derry Rd. - Hwy 25	-	1400	2
	(3) QEW - Hwy 25	-	1500	**
PI-1N to LF-2N	(1) Britannia Rd. - Fourth Line - Hwy 401 - Hwy 10	-	250	1+
	(2) *Britannia Rd. - Tremaine Rd. Steeles Ave. - Hwy 25 - Hwy 401 - Hwy 10	-	350	2
(ii)LF-2N /PI-13N to PI-13N	(1) Hwy 401 - Fourth Line - Britannia Rd. - Fifth Line	-	-	1+
	(2) *Hwy 401 - Fourth Line - Derry Rd. - Fifth Line	200	-	2
	(3) *Hwy 401 - Trafalgar Rd. - Britannia Rd. - Fifth Line	-	5600	3
	(4) QEW - Hwy 25 - Britannia Rd. - Fifth Line	-	1750	**
PI-13N to LF-2N	(1) *Fifth Line - Britannia Rd. - Trafalgar Rd. - Hwy 401 - Hwy 10	-	5600	3
	(2) Fifth Line - Britannia Rd. - Fourth Line - Hwy 401 - Hwy 10	-	-	1+
	(3) *Fifth Line - Derry Rd. - Fourth Line - Hwy 401 - Hwy 10	200	-	2
	(4) *Fifth Line - Britannia Rd. - Trafalgar Rd. - Derry Rd.	-	7350	4

* Options eliminated in preliminary Phase 4A screening of access route options

+ Preferred Access Road identified by Site Selection Team

** Preferred options resulting from Phase 3B screening of access route options (not considered in comparative evaluation of access routes).

Table 2
Page 3 of 3

HYDROGEOLOGIC RANKING OF ACCESS ROAD OPTIONS

SITE	ACCESS ROAD OPTION	SENSITIVE LANDS (m)		HYDRO-GEOLOGICAL RANKING
		Local Roads	Regional Rds.	
B. Partially Integrated				
(iii) LF-4N/PI-1N to LF-4N	(1) Hwy 401 - Fourth Line - Britannia Rd.	-	1400	1+
	(2) *Hwy 401 - Fourth Line - Derry Rd. - Hwy 25 - Britannia Rd.	-	1400	1
	(3) QEW - Hwy 25 - Britannia Rd.	-	1500	**
PI-1N to LF-4N	(1) Hwy 25 - Britannia Rd.	-	-	1
	(2) First Line - Britannia Rd.	-	-	1+
(iv) LF-1E /PI-27E to PI-27E	(1) QEW - RR 47	-	-	1+
	(2) QEW - RR 47 - RR 98	-	-	1
PI-27E to LF-1E	Same as LF-1E integrated			

* Options eliminated in preliminary Phase 4A screening of access route options

+ Preferred Access Road identified by Site Selection Team

** Preferred options resulting from Phase 3B screening of access route options (not considered in comparative evaluation of access routes).

Transportation (M.M. Dillon Limited, 1985b). The first zone (170 m) represents the area flanking each side of a rail spur line within which the maximum noise impacts could be expected to occur. The 250 m impact zone is based on a Transport Canada study on the Mississauga train derailment and represents the area outside of which the impact of short range catastrophic events are expected to be minimal. The reader should refer to the M.M. Dillon Limited Transportation report for a more complete discussion of the impact zones.

Rail access options were identified by M.M. Dillon Limited in consultation with the other site selection consultants. Those options are shown in Figures C16 through C21, Appendix C.

A number of major constraints identified in M.M. Dillon Limited, 1985a were associated with provision of rail service to LF-2N and PI-13N. It was therefore assumed that rail service was not an opportunity for these sites.

2.4.1 FACTOR IDENTIFICATION

The hydrogeologic factor, "Distance Through Hydrogeologically Sensitive Lands", identified to address concerns arising from the accidental spillage of waste during transport along access roads, was considered equally appropriate for transport of process additives and reagents by rail. This factor encompasses considerations specific to geologic conditions which may exist along the rail access that could allow for the subsurface migration of liquid additives and reagents from the spill site. As with spills along access roads, it is assumed that spills during rail service would be attended to promptly.

2.4.2 FACTOR APPLICATION

The analysis of rail access options is based on the distance travelled over sensitive lands between the main line and the central operating area. An impact zone 250 m wide was used in this analysis. This width was considered most appropriate for the assessment of impacts resulting from catastrophic events (M.M. Dillon Limited, 1985b). The reader should refer to Section 2.3.1 for a definition of "sensitive lands".

Sensitive lands along the rail access options were identified and measured. The rail access options are identified by the option number provided in M.M. Dillon Limited, 1985a. Information on surficial geology along the options is available from published geology maps and from constraint mapping completed during Phase 3B. The measured lengths (off and onsite) for each rail access option are provided in Table 3. These options were ranked from most preferred to least preferred in the same manner as the access roads.

With the exception of Option 3 at LF-9C, for which 80 m of sensitive lands (a flood plain) are identified, no sensitive lands are identified along the remaining options.

The linear distances through sensitive lands and the ranking was provided to the site selection coordinating consultant for inclusion in the comparison of rail access options.

Table 3

HYDROGEOLOGIC RANKING OF RAIL ACCESS OPTIONS

SITE	RAIL ACCESS OPTIONS	SENSITIVE LAND (m)		HYDRO-GEOLOGIC RANKING
		OFF SITE	ON THE SITE	
LF-4N	Option 1	-	-	1+
	Option 2	-	-	1
	Option 3	-	-	1
	Option 4	-	-	1
PI-1N	Option 1	-	-	1
	Option 2	-	-	1+
	Option 3	-	-	1
	Option 4	-	-	1
LF-3C	Option 1	-	-	1
	Option 2	-	-	1+
	Option 3	-	-	1
LF-9C	Option 1	-	-	1
	Option 2	-	-	1
	Option 3	80	-	5
	Option 4	-	-	1+
	Option 5	-	-	1
PI-27E	Option 1	-	-	1+
LF-1E	Option 1	-	-	1+
	Option 2	-	-	1
	Option 3	-	-	1
	Option 4	-	-	1

Rail options shown on Fig. C16 to C21, Appendix C

+ Preferred rail access options identified by site selection team.

3.0 COMPARISON OF SITING OPTIONS

3.1 INTRODUCTION

Hydrogeologic input to the comparison of siting options involved the differentiation of sites based on:

- the natural capability of the hydrogeologic setting to contain potential contaminant releases from OWMC facilities;
- the characteristics of ground water resources potentially affected by contaminant releases and alternatives to these ground water resources; and
- the sensitivity of the geologic settings along access roads to transportation spills.

Rail service is viewed as an opportunity for the bulk haulage of process additives and reagents rather than as an absolute requirement of a siting option. No differences were identified in the assessment of the sensitivity of geologic settings along the preferred rail access options identified in Table 3, Section 2.4.2. It was therefore, not possible to differentiate siting options based on the sensitivity of the geologic setting along the preferred rail access option. Further analyses based on this consideration were not undertaken.

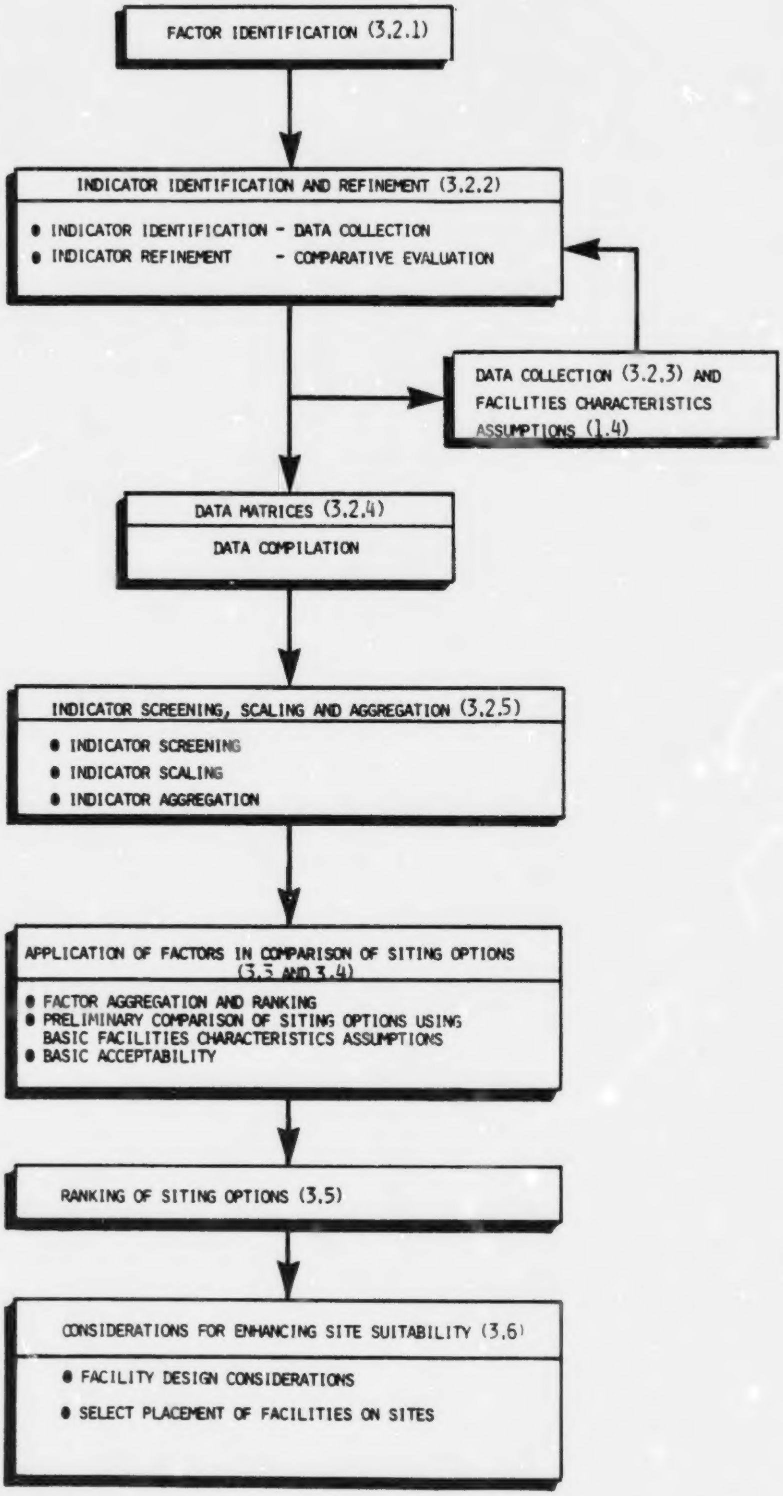
The methodology used in conducting the comparison of siting options is summarized in Figure 8. The process basically involved the reduction of a large number of differences among the siting options to a smaller number of factors which lend themselves to ready comparison. These factors (Section 3.2.1), are intended to assist in providing a preliminary evaluation of the potential risks and impacts associated with site development. In addition, they are intended to provide the basis for a preliminary identification of mitigative measures.

Where possible, the factors were divided into a number of indicators (Section 3.2.2). Initially, indicators were developed to focus data collection efforts. With the collection of information on each of the candidate sites, the indicators were refined by combining various data. These refined indicators are designed to provide measures of the relative risk potential linked to the various contaminant pathways and the ground water receptor. Following the refinement of the indicators, data matrices were prepared highlighting the relative differences amongst the siting options. These matrices are briefly described in Section 3.2.4 and provided in Appendix D.

It was subsequently necessary to drop some indicators from further consideration because there were little or only minor differences among options (Section 3.2.5). The remaining indicators were scaled in units of desirability and combined (process of aggregation) to provide suitability rating indices for the factors (Section 3.2.5).

The application of factors and indicators and the

FIGURE 8
EVALUATION PROCESS FOR COMPARISON OF SITING OPTIONS


FACTOR IDENTIFICATION (3.2.1)
INDICATOR IDENTIFICATION AND REFINEMENT (3.2.2)
● INDICATOR IDENTIFICATION - DATA COLLECTION
● INDICATOR REFINEMENT - COMPARATIVE EVALUATION
DATA COLLECTION (3.2.3) AND FACILITIES CHARACTERISTICS ASSUMPTIONS (1.4)
DATA MATRICES (3.2.4)
DATA COMPILATION
INDICATOR SCREENING, SCALING AND AGGREGATION (3.2.5)
● INDICATOR SCREENING
● INDICATOR SCALING
● INDICATOR AGGREGATION
APPLICATION OF FACTORS IN COMPARISON OF SITING OPTIONS (3.3 AND 3.4)
● FACTOR AGGREGATION AND RANKING
● PRELIMINARY COMPARISON OF SITING OPTIONS USING BASIC FACILITIES CHARACTERISTICS ASSUMPTIONS
● BASIC ACCEPTABILITY
RANKING OF SITING OPTIONS (3.5)
CONSIDERATIONS FOR ENHANCING SITE SUITABILITY (3.6)
● FACILITY DESIGN CONSIDERATIONS
● SELECT PLACEMENT OF FACILITIES ON SITES

actual comparisons of siting options are presented in Sections 3.3 to 3.5. Issues relating to the basic acceptability of individual sites and considerations for site enhancment are discussed in Section 3.6.

3.2 COMPARATIVE METHODOLOGY

3.2.1 FACTOR IDENTIFICATION

Three factors were identified at the beginning of Phase 4A:

(1) Capability of Providing Natural Containment;
(2) Impact on Ground Water Use; and
(3) Distance Through Hydrogeologically Sensitive Lands

The 'Capability to Provide Natural Containment' and the 'Impact on Ground Water Use' factors are grouped in the 'site vicinity' study zone. Although the 'Capability to Provide Natural Containment' factor is a measure of onsite containment, potential impacts are, by regulation, assessed at the site boundary. As described earlier, the 'site vicinity' is defined as an area extending approximately two kilometres outwards from the centre of each site.

The 'Distance Through Hydrogeologically Sensitive Lands' factor was included in order to differentiate amongst the siting options based on the length of sensitive lands along the preferred access roads to the sites.

3.2.1.1 Capability of providing natural containment

The 'Capability of Providing Natural Containment' factor encompasses those characteristics of the geologic/hydrogeologic environment which influence the migration of potential contaminants. This factor is specifically intended as a measure of the capacity of the environment to naturally retard contaminant movement to underlying aquifers.

There are three main hydrogeologic pathways by which contaminants could move offsite:

(1) downward movement through the confining layer to underlying permeable deposits or aquifers which extend offsite;

(2) movement along man-made structures which either extend laterally offsite or downward to permeable deposits or aquifers; and

(3) lateral movement through the shallow fractured zone of the confining layer.

The first two pathways are addressed in the 'Capability to Provide Natural Containment' factor and are discussed in Section 3.2.2. The third pathway, the fractured zone, is briefly discussed in the following paragraphs.

Fractured zone pathway. There is a potential for contaminants originating at either the landfill or the central operating area to enter the shallow subsurface and be transported laterally in the fractured (weathered) zone which is present at all of the candidate sites. This pathway theoretically could lead to receptors in any of the following ways:

- Contaminants could move offsite in the fractured zone then interact with the surface water system beyond the limits of any onsite surface water controls. This could potentially result in surface water contamination.

- Contaminants could move offsite in the fractured zone to ponds, leaking cisterns, or shallow dug wells.

- Contaminants could move offsite in the fractured zone then downward through the confining layer to underlying aquifer(s). This would be particularly important where thinner confining layers occur in the vicinity of a site.

Research is presently being carried out at the University of Waterloo (Dr. John Cherry, personal communication) to assess the significance of the fractured zone as a pathway for contaminant movement. Preliminary indications are that this pathway may not pose a serious constraint to site development because infilling and poor fracture interconnection would tend to reduce the effectiveness of fractures in the movement of contaminants.

While not directly related to the fractured zone pathway, one additional source of contaminants is the development of leachate seeps or springs on the flanks of landfills which extend above ground surface. Such seeps can be expected to occur when landfills are constructed in low hydraulic conductivity soils and leachate is not collected. This results from ground water mounding within the landfill.

It should be recognized that the potential for contaminant movement both through shallow subsurface fractures, and as a result of seeps or springs on the landfill flanks, exists at all candidate sites being considered in this study. Early monitoring detection systems and engineered safeguards, such as perimeter collection systems, are available and could be utilized to intercept contaminants before they move beyond the site boundry. These safeguards would be essential to facility operations regardless of location and as such, the requirement for their use is not expected to influence the site selection process.

Fracture flow and contaminant transport in fractured porous media are complex phenomena for which there is presently little information. A more quantitative assessment of this potential pathway should be undertaken at the preferred site(s) during Phase 4B to address its long term implications and to determine the most effective means of controlling contaminant transport in the fractured zone, if needed.

3.2.1.2 Impact on ground water use

All considerations specific to local ground water resources are represented by a general 'Impact on Ground Water Use' factor. This factor encompasses the characteristics of the resource, uses of the resource, and the existence of alternative ground water sources.

3.2.1.3 Distance through hydrogeologically sensitive lands

The site selection team identified preferred access roads during the refinement of siting options. These preferred access roads identified in Table 2, Section 2.3, were carried forward by the site selection team into the multidisciplinary comparison of siting options. The involvement of the hydrogeologic consultant was limited to providing the transportation consultant (M.M. Dillon Limited) with the 'Distance Through Hydrogeologically Sensitive Lands' data for the preferred access roads (presented in Table 2), for synthesis with other transportation spill risk indicators. The reader should refer to the Transportation report titled Site Selection Process, Phase 4A: Selection of a Preferred Site(s) - Transportation (M.M. Dillon Limited, 1985b) for a discussion of how the 'sensitive lands' data were used.

3.2.2 INDICATOR IDENTIFICATION

3.2.2.1 Indicator identification - data collection

In order to focus data collection efforts, two hydrogeologic factors were initially subdivided into five indicators:

(1) Capability to Provide Natural Containment
  - Confining layer characteristics
  - Ground water flow system
  - Other contaminant pathways

(2) Impact on Ground Water Use
  - Aquifer
  - Existing ground water use and potential demand

The indicators defined in greater detail below, represent an amalgamation of several groups or sets of data. The data base collected using these indicators is presented in the individual site reports (technical appendices).

Confining layer characteristics. This indicator represents a grouping of the various physical properties and related considerations which govern flow through fine-textured materials (confining layer). This includes such measurable parameters as thickness, observations such as texture, and interpretive considerations such as hydraulic conductivity and porosity. Information on the confining layer at each site is contained in the individual technical appendices.

Ground water flow system. This indicator relates to the movement of ground water in the subsurface. The direction and rate of movement is dependent on the hydraulic characteristics (porosity and hydraulic conductivity) of the geologic materials and the hydraulic gradient. The hydraulic gradient is a measure of the difference in presure or head between two points along the path of flow. Water level measurements for domestic water wells were used to provide a general indication of pressure or head. Ground water moves in the direction of decreasing head. Although contaminant movement is highly specific to the site and the contaminant, the rate of ground water movement can provide a general estimate of the rate of travel for a non-reactive contaminant. The resultant velocity estimates are conservative since physical, chemical and biochemical processes will in most cases, reduce the rate of movement. Estimates of ground water flow velocity based on Darcy's Law are contained in the individual technical appendices. A more detailed assessment of ground water flow using advection/diffusion is contained in Appendix A of this report.

Other contaminant pathways. This indicator refers to man-made structures including existing and abandoned wells (both water and petroleum wells), drainage tiles, and excavations backfilled with permeable materials which may provide potential contaminant pathways. Information on these structures was obtained from data sources such as well records, field survey work and interviews with local residents (commonly referred to as the "Walk and Talk" survey).

Aquifer. This indicator focuses discussion on the characteristics of local ground water resources, namely the productivity of local aquifers and the quality of the ground water. Information on locally and regionally significant aquifers was obtained from a review of published and unpublished reports.

Existing ground water use and potential demand. This indicator provides information on existing and potential ground water use. Existing use is identified in the "Walk and Talk" survey forms.

3.2.2.2 Indicator refinement - comparative evaluation

The indicators used in the collection of data were refined to reflect the relative risk potential associated with the various contaminant pathways, and the characteristics of the ground water resources which could potentially be affected. The refined indicators consist of individual elements of the previously identified indicators and combinations of these elements. These refined indicators are shown in Figures 9 and 10.

Predictability of geologic condition. This indicator was introduced as a measure of the geologic uniformity of the confining layer present below the individual sites.

Figure 9
Development Of Indicators For Capability Of Providing Natural Containment Factor

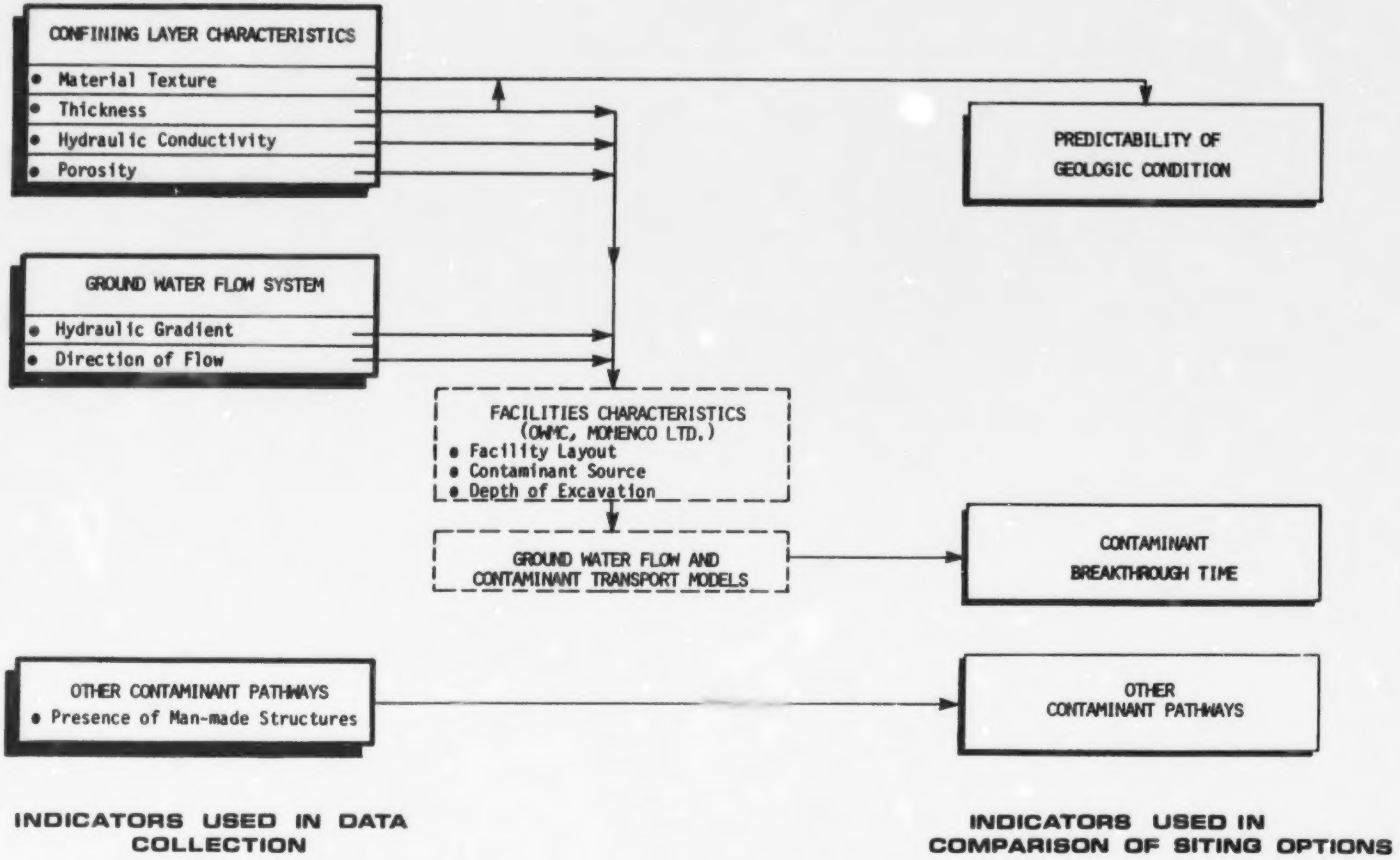
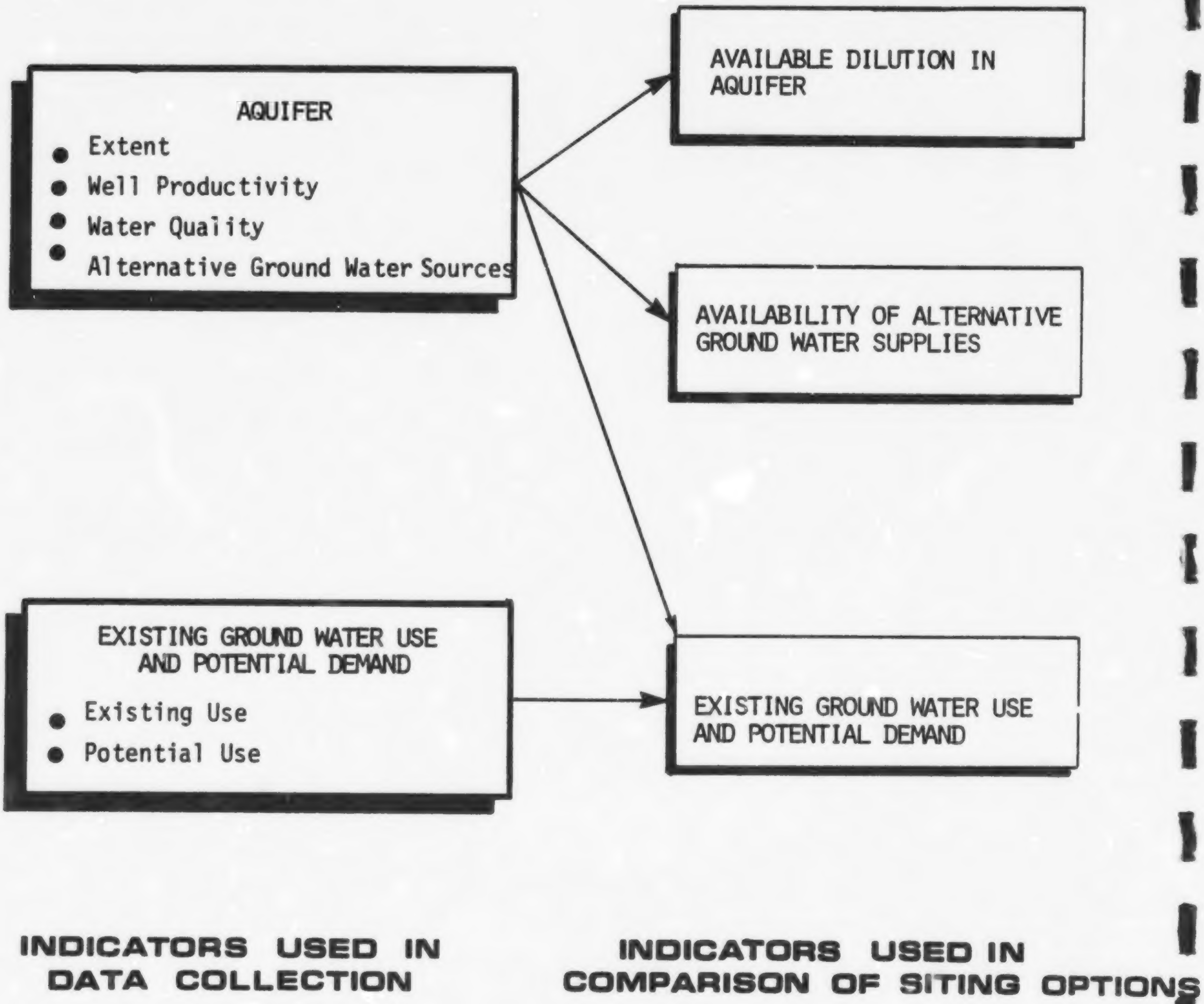

CONFINING LAYER CHARACTERISTICS
• Material Texture
• Thickness
• Hydraulic Conductivity
• Porosity
GROUND WATER FLOW SYSTEM
• Hydraulic Gradient
• Direction of Flow
FACILITIES CHARACTERISTICS (OWMC, MONENCO LTD.)
• Facility Layout
• Contaminant Source
• Depth of Excavation
GROUND WATER FLOW AND CONTAMINANT TRANSPORT MODELS
OTHER CONTAMINANT PATHWAYS
• Presence of Man-made Structures
PREDICTABILITY OF GEOLOGIC CONDITION
CONTAMINANT BREAKTHROUGH TIME
OTHER CONTAMINANT PATHWAYS
INDICATORS USED IN DATA COLLECTION
INDICATORS USED IN COMPARISON OF SITING OPTIONS

Figure 10
Development Of Indicators For Impact On Ground Water Use Factor


AQUIFER
● Extent
● Well Productivity
● Water Quality
● Alternative Ground Water Sources
EXISTING GROUND WATER USE AND POTENTIAL DEMAND
● Existing Use
● Potential Use
AVAILABLE DILUTION IN AQUIFER
AVAILABILITY OF ALTERNATIVE GROUND WATER SUPPLIES
EXISTING GROUND WATER USE AND POTENTIAL DEMAND
INDICATORS USED IN DATA COLLECTION
INDICATORS USED IN COMPARISON OF SITING OPTIONS

The confining layer is defined as the uppermost geologic unit(s) of fine textured soil (predominantly silt-clay) having a low permeability. Ground water and contaminant movement through such materials is predictably slow. The interpretation of uniformity is based on:

- observed lateral and vertical textural consistency in the confining layer; and

- uniform thickness of the confining layer across the site.

Contaminant breakthrough time. This indicator was introduced as a measure of the capacity of the confining layer to retard contaminant migration. The approach used in determining breakthrough times varied depending on the type of facility proposed. Details are contained in Appendix A of this report. For a landfill, breakthrough times were determined by:

- superimposing facility layouts (based on site adapted considerations) onto geologic cross-sections prepared for each site and identifying the potential source of contaminants (i.e. leachate produced from the solidified mass in the landfill);

- identifying the potential pathway for migration of contaminants to the ground water receptor; and

- calculating the contaminant breakthrough time at specified contaminant concentrations using ground water flow and contaminant transport models (Appendix A).

Breakthrough for the landfill is determined as the point in time at which a contaminant such as chloride moves downward through the confining layer and discharges to the underlying aquifer at either the peak contaminant concentration or a specified concentration. Specified concentration values are presented as a fraction of the initial contaminant source concentration (C/Co), where C is the concentration at the aquifer and Co is the contaminant concentration at the source. Chloride is considered a representative 'worst case' contaminant because its movement in the subsurface is not readily affected by attenuation processes. Attenuation processes would effectively increase the elapsed time to contaminant breakthrough. The reduction of contaminant concentrations is assumed to occur as a result of advection/ dispersion processes, only.

The analysis of breakthrough time assumes that the contaminant source is constant with time, namely that the waste residue will leach at a constant rate over the time interval to the breakthrough point. For sites where the breakthrough concentrations time is equal to or less than the lifespan of significant leachate production, this assumption will be valid. If the leachate source persists until such time as breakthrough of approximately C/Co = 1.0 occurs, then discharge to the aquifer will be at full leachate concentration assuming no attenuation takes place.

If, on the other hand, the leachate source decays below contaminant concentration levels of concern prior to breakthrough at the aquifer, molecular diffusion could spread the contaminant plume to the extent that concentrations of concern may never be encountered at the aquifer.

Contaminant breakthrough times for the central operating area were determined based on the assumption that the contaminant source, could be either a residue from a spill, or a minor leak which may not be readily detected and as such, could continue unmitigated over the active life of the facility. Upon decommissioning of the central operating area, any waste residues would subsequently be removed and disposed.

The following assumptions were used for calculation of contaminant breakthrough for the central operating area:

- that contaminants are released either as a residue resulting from a spill or as a continuous leak at a point source (such as a holding pond);
- the contaminant plume moves under steady state uniform flow conditions;
- the plume spreads outwards along the flow path due to advection/dispersion resulting in a reduction in contaminant concentrations within the plume; and
- breakthrough is determined as the time required for the contaminant plume at peak concentration to reach the aquifer.

The models used in determining contaminant breakthrough times and the peak concentration values for the landfill and central operating area are described in Appendix A.

It should be noted that breakthrough times are sensitive to changes in the parameters used in the calculations; namely, confining layer hydraulic conductivity, porosity, thickness and the hydraulic gradient through the layer. With the exception of confining layer thickness which was measured at the boreholes, the other parameters are based on literature review and interpretive assumptions. This is considered to be acceptable for purposes of site comparison. Those parameters will be assessed in more detail on the preferred site(s) during Phase 4B. A discussion of the limitations of the models used in determination of breakthrough times is also provided in Appendix A.

Other contaminant pathways. This indicator was carried forward from the data collection step in order to differentiate sites based on the number of man-made structures which would potentially need to be addressed. For a more detailed explanation see the 'Capability of Providing Natural Containment' natural containment factor sheet in Appendix B.

Available dilution in aquifer. This indicator was introduced to provide a qualitative assessment of the potential for contaminant dilution in the principal aquifer(s) present below each of the candidate sites. Some contaminants such as nonreactive ions (e.g. chloride) and persistent organic compounds, are relatively unaffected by attenuation processes and may only be reduced in concentration by dilution. Dilution in the subsurface occurs where the contaminants spread out from the flow path as a result of mechanical dispersion and molecular diffusion. Contaminant movement, even following dilution in the aquifer, may result in some degradation of the local ground water quality.

From a regulatory perspective, it is likely that the use of ground water to dilute persistent contaminants will be an acceptable practice as long as it can be demonstrated that the resulting degradation of water quality will not affect the reasonable use of the water beyond the site boundary (Ontario Ministry of the Environment, 1984).

Availability of alternative ground water supplies. This indicator was introduced to identify alternative ground water supplies in the event that the current principal source of supply is contaminated and can no longer be used. An alternative supply is defined as a communal well capable of providing an adequate supply of water equal to or better in quality than the supply to be replaced. Other sources of supply, including hauled water and municipal services, have not been considered in this assessment.

The selection of an alternative ground water source requires the alternative supply to either be:

- hydrogeologically isolated from both the source of contamination and the original source of supply which could become contaminated; or

- sufficiently removed from the contaminated area so that any potential impacts would be negligible.

The alternative source should also be within a reasonable distance from the location where it would be required to reduce water transport costs. All distances would need to be assessed on a site-by-site basis to identify optimum separation from potential contaminant sources.

Similarly, a future consideration of alternative supplies, if required, should also address the availability of other sources of supply such as hauled water and municipal water services.

Existing ground water use and potential demand. This indicator was carried forward into the comparative evaluation in an effort to differentiate the siting options based on:

- the extent of existing ground water use; and
- the capability of local aquifers to accommodate water quantity and quality requirements imposed by demanding users such as communities and/or industries.

Ground water use information from interviews conducted during the 'Walk and Talk' survey is summarized in Table 4. Not all residents were available to be interviewed and some residents declined comment. Consequently, this information was not considered to be sufficiently complete to differentiate siting options based strictly on water use. It was evident from these interviews however, that ground water is used in the vicinity of all the candidate sites as a source of household and farm supply. The interviews were also useful when combined with published water resource studies and

TABLE 4

EXISTING GROUND WATER USE ON SITE AND IN THE IMMEDIATE SITE VICINITY
(Based On Walk And Talk Survey)

SITING OPTION	INTERVIEWS	TOTAL NUMBER OF WELLS	WELLS USED FOR HOUSEHOLD PURPOSES		WELLS USED FOR HOUSEHOLD AND AGRICULTURAL PURPOSES	WELLS USED FOR AGRICULTURAL PURPOSES	WELLS ABANDONED OR NOT IN USE	WELL USE NOT SPECIFIED	HOUSEHOLDS WITH CISTERNS
			UNDIFFERENTIATED USE	USE OTHER THAN DRINKING					
LF-2N/ PI-1N	64	85	45 53%	2 2%	11 13%	9 11%	15 18%	3 3%	10 16%
LF-2N/ PI-13N	43	47	26 55%	4 8%	0 0%	6 13%	5 11%	6 13%	9 21%
LF-4N/ PI-1N	65	87	44 51%	1 1%	14 16%	7 8%	19 22%	2 2%	14 22%
LF-4N/ PI-13N	65	74	40 54%	3 4%	7 9%	5 7%	13 18%	6 8%	17 26%

TABLE 4 (cont'.)

EXISTING GROUND WATER USE ON SITE AND IN THE IMMEDIATE SITE VICINITY
(Based On Walk And Talk Survey)

SITING OPTION	INTERVIEWS	TOTAL NUMBER OF WELLS	WELLS USED FOR HOUSEHOLD PURPOSES		WELLS USED FOR HOUSEHOLD AND AGRICULTURE PURPOSES	WELLS USED FOR AGRICULTURAL PURPOSES	WELLS ABANDONED OR NOT IN USE	WELL USE NOT SPECIFIED	HOUSEHOLDS WITH CISTERNS
			UNDIFFERENTIATED USE	USE OTHER THAN DRINKING					
LF-3C	30	24	4 17%	1 4%	1 4%	8 33%	10 42%	-	19 63%
LF-9C	17	13	3 23%	-	4 31%	6 46%	-	-	12 70%
LF-1E	45	20	8 40%	-	2 10%	5 25%	4 20%	1 5%	30 67%
LF-1E/ PI-27E	54	27	9 34%	1 4%	4 15%	5 18%	5 18%	3 11%	34 63%

water well records to highlight relative differences in the productivity (amount of water that is available) and water quality of the various local aquifers. Productive, good quality aquifers may be capable of supplying the water requirements of more demanding users such as communities, industry, and even municipalities. On the other hand, marginal aquifers may only be capable of supplying the basic needs of individual households.

3.2.3 DATA COLLECTION

The methodology employed in the collection of the geologic/hydrogeologic data base is summarized in Figure 11 and detailed in the accompanying technical appendix reports for each of the sites. The information base includes:

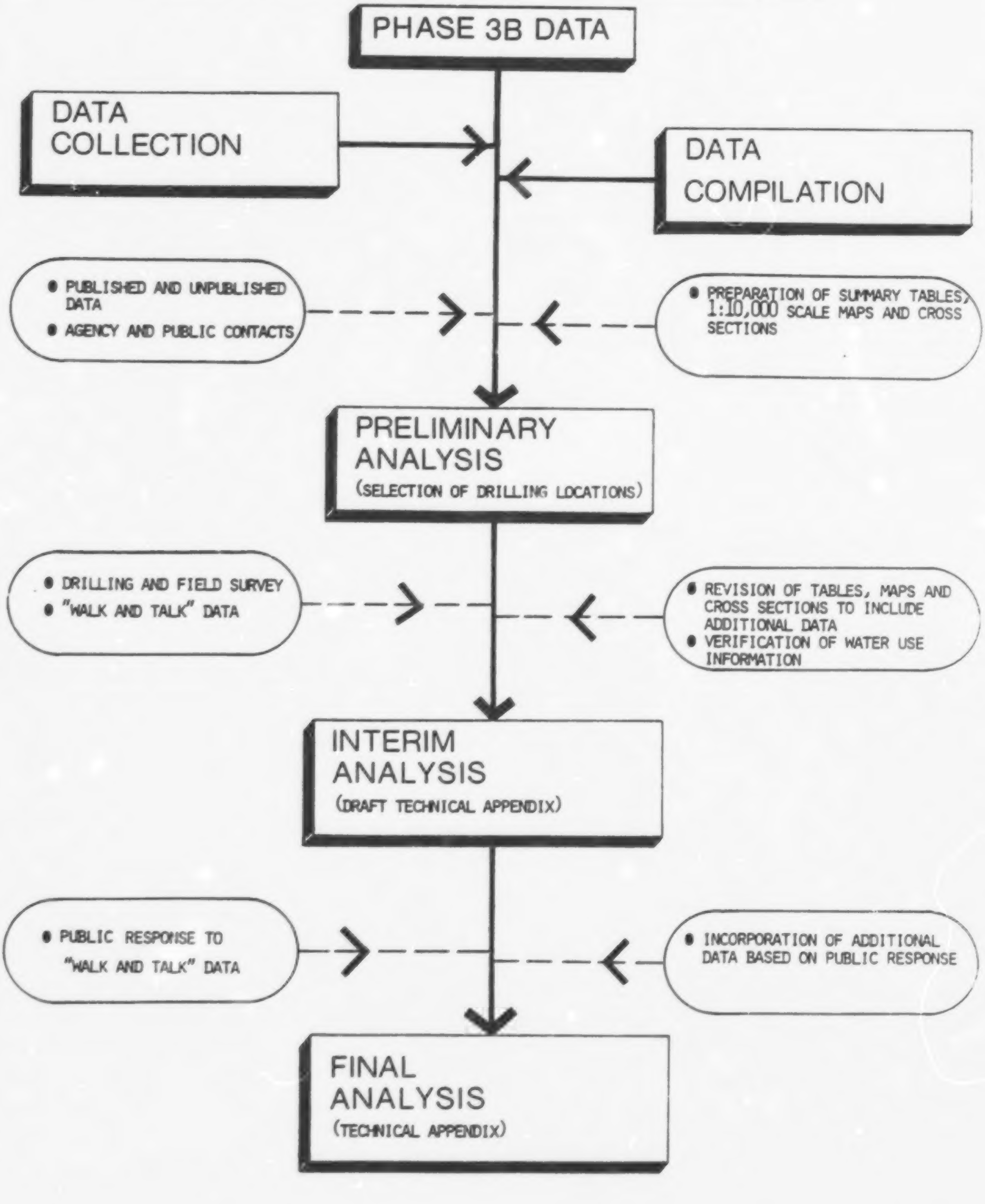
- data collected during earlier phases such as water well records, published and unpublished reports, and maps;

- data collected as a result of interviews with government agency personnel and local residents ("Walk and Talk" survey in particular information on ground water use and potential contaminant pathways;

- geologic data collected during site drilling and site visits; and

- hydrogeologic and geotechnical data on the hydraulic and geotechnical properties of the geologic materials present at the sites (information from published and unpublished studies).

Figure 11
Data Collection
Methodology Flow Chart


PHASE 3B DATA
DATA COLLECTION
DATA COMPILATION
• PUBLISHED AND UNPUBLISHED DATA
• AGENCY AND PUBLIC CONTACTS
• PREPARATION OF SUMMARY TABLES, 1:10,000 SCALE MAPS AND CROSS SECTIONS
PRELIMINARY ANALYSIS
(SELECTION OF DRILLING LOCATIONS)
• DRILLING AND FIELD SURVEY
• "WALK AND TALK" DATA
• REVISION OF TABLES, MAPS AND CROSS SECTIONS TO INCLUDE ADDITIONAL DATA
• VERIFICATION OF WATER USE INFORMATION
INTERIM ANALYSIS
(DRAFT TECHNICAL APPENDIX)
• PUBLIC RESPONSE TO "WALK AND TALK" DATA
• INCORPORATION OF ADDITIONAL DATA BASED ON PUBLIC RESPONSE
FINAL ANALYSIS
(TECHNICAL APPENDIX)

Complete lists of references and government agency and public interest groups contacted are provided in Section 5.0.

3.2.4 DATA MATRICES

A number of data matrices (Appendix D) were prepared for each of the indicators using the extensive geologic/hydrogeologic data base presented in the technical appendices. These matrices highlight the relative differences amongst the siting options. Table D1 presents a summary of geologic conditions on the various sites. Contaminant breakthrough times are presented in Tables D2 and D3 for the landfill, and the central operating area contaminant leakage scenarios, respectively. The characteristics of ground water resources in the vicinity of the sites which could potentially be considered as sources of alternative water supplies are presented in Table D4. Table D5 is a summary of aquifer characteristics below and in the vicinity of the sites.

3.2.5 INDICATOR SCREENING, SCALING AND AGGREGATION

Following collection of data on each of the indicators, the indicators were (1) reassessed to exclude or screen out indicators which could not be used in the comparative evaluation; (2) ranked in order of importance; and (3) subsequently were combined to highlight the principal issues. These three steps known as screening, scaling and aggregation are defined as follows:

Screening - A review process designed to identify and delineate indicators for which there are no data values, no differences among options, insignificant impacts, or duplication of issues. Indicators left after screening were carried forward in the comparative evaluation.

Scaling - The conversion of data to units of desirability, such as high, medium or low is referred to as scaling.

Aggregation - Aggregation refers to the process by which indicators were combined to highlight key decision-making issues.

3.2.5.1 Indicator screening

As is shown in Figures 9 and 10, elements of four of the data collection indicators - 'Confining layer characteristics', 'Ground water flow system', 'Aquifer' and 'Existing ground water use and potential demand' were incorporated into the six refined indicators introduced to differentiate amongst the siting options.

Two of these refined indicators were subsequently screened:

(1) Other Contaminant Pathways; and
(2) Available Dilution In Aquifer.

The 'Other contaminant pathways' indicator was screened because man-made structures were identified at all sites (Table 5). The presence (or absence) of man-made structures therefore could not be used effectively to differentiate amongst siting options. It should also be noted that remedial measures including excavation of these structures and sealing of wells are available that would mitigate

TABLE 5

SUMMARY OF POTENTIAL MAN-MADE CONTAMINANT PATHWAYS AT CANDIDATE SITES

SITE / POTENTIAL CONTAMINANT PATHWAY	OIL AND GAS WELLS	WATER WELLS	BACKFILLED EXCAVATION	TILE DRAINAGE
LF-3C	x	x	x	x
LF-9C	x	x	x	x
LF-1E	x	x	x	
PI-27E		x	x	
LF-2N		x	x	
PI-13N		x	x	
PI-1N		x	x	
LF-4N		x	x	

x Presence of Potential Contaminant Pathway the risk associated with contaminants moving through these potential pathways to local receptors.

The 'Available dilution in aquifer' indicator was screened because site specific information needed for assessing the available dilution in local aquifers such as aquifer thickness, hydraulic conductivity and hydraulic gradient, is currently not available. This information was not considered essential at this time for comparing the siting options but rather would be collected during Phase 4B.

3.2.5.2 Indicator scaling

In order to compare sites it was necessary to convert or combine descriptive and/or numerical physical units into units of comparison by differentiating them based on desirability. For example, contaminant breakthrough times calculated in years (Tables D2 and D3) are expressed as being long, variable or short, with preference being given to sites with long breakthrough times.

Tables 6 and 7 present the scaling systems applied to the indicators of the 'Capability to Provide Natural Containment' and 'Impact on Ground Water Use' factors.

Predictability of geologic conditions. The confining layer present below and in the immediate vicinity of the individual sites can be interpreted as being either uniform, locally variable, or variable (Table 6).

'Uniform' is defined as a confining layer which is continuous and exhibits lateral and vertical textural

TABLE 6

SCALING SYSTEMS APPLIED TO INDICATORS OF " CAPABILITY TO PROVIDE NATURAL CONTAINMENT " FACTOR

INDICATOR	INDICATOR LEVEL	RATIONALE
Predictability of Geologic Condition	Uniform	The confining layer is continuous and laterally and vertically uniform. The direction and rate of contaminant movement through the confining layer is potentially predictable.
	Locally Variable	The confining layer variability is attributed to locally occurring geologic features in the form of sand layers within the confining layer which may be laterally continuous. Some level of uncertainty exists with respect to the direction and rate of contaminant movement. The areal extent of the sand may be mappable and the level of uncertainty reduced.
	Variable	The confining layer contains granular zones or layers which could significantly affect the interpretation of confining layer thickness. These granular zones could act as potential contaminant pathways and therefore represent constraints to site development. The location of these zones would be difficult to predict.
Contaminant Breakthrough	Long	Site underlain by a thick uniform confining layer; movement of conservative contaminants through the confining layer is estimated to be in the hundreds or thousands of years across the site.
	Variable	Site underlain by a confining layer which locally varies in thickness; contaminant movement through the confining layer is anticipated to vary substantially across the site.
	Short	Site underlain by a thin confining layer; contaminant movement through the confining layer is estimated to occur relatively rapidly (within a few to tens of years).
Other Contaminant Pathways	Not Applicable	This indicator was screened. Man-made structures were identified at all sites. Remedial measures are available which would greatly reduce the risk associated with contaminants moving through these potential pathways to local receptors.

TABLE 7

SCALING SYSTEMS APPLIED TO INDICATORS OF "IMPACT ON GROUND WATER USE" FACTOR

INDICATOR	INDICATOR LEVEL	RATIONALE
Available Dilution in Aquifer	not applicable	This indicator was screened. Information on the thickness, permeability and hydraulic gradient in the underlying aquifer which is required in the assessment of dilution, is not available. It is therefore not possible to assess whether the dilution in the local aquifer(s) is adequate with respect to contaminants which could potentially be emitted from the facilities.
Availability of Alternative Ground Water Supplies	No	Existing aquifer is sole source of supply. Alternative supplies are not available.
	Yes	Alternative sources of ground water supplies are available in the general vicinity of the site.
Existing Ground Water Use and Potential Demand	Limited	Aquifer use is limited to domestic and agricultural requirements because of water quantity and/or quality considerations.
	Potential for Expansion	Aquifer may be capable of meeting more stringent water use requirements.

uniformity. Contaminant movement through a uniform confining layer would be predictable.

The 'locally variable' interpretation was assigned to those sites with localized areas of stratigraphic variability represented by sand layers within the confining layer. Based on the drilling program, these localized areas of variability are associated with distinct geologic features. The extent of these features may be mapped and the level of uncertainty reduced. For example, a morainal feature has been identified immediately to the east of LF-1E. Sand layers associated with this feature may extend below the site. Should these sand layers be present below the site, the confining layer can be expected to be thin and contaminant breakthrough time would be correspondingly short. It may be possible to isolate the extent of these sand features with a detailed site study.

Variable is defined as the observed or inferred presence of sand layers within the confining layer. These sand layers could significantly affect the interpretation of confining layer thickness. The sand layers are not associated with a distinct geologic feature and their presence and extent are not predictable. The sand layers may act as potential pathways for off-site migration and therefore could represent a constraint to facility development.

Table D1, Appendix D presents the indicator level ratings for the various sites under consideration. Preference is given to sites underlain by a uniformly textured and thick confining layer over sites with observed or inferred geologic variability.

Contaminant breakthrough time. A three level scale was developed for this indicator (Table 6). In general, breakthrough time values (Tables D2 and D3, Appendix D) are highly clustered and can be expressed as either long or short. A third level, 'variable' was introduced for those sites identified as having 'locally variable' geologic conditions (based on the Predictability of geologic condition indicator). For example at LF-1E, breakthrough time values are anticipated to range from long to short depending on location on the site. The 'variable' rating assigned to this site reflects the uncertainty associated with the geologic conditions and does not reflect the breakthrough time values calculated for the site. The rating could potentially be adjusted upwards (to long) by eliminating those portions of LF-1E underlain by shallow sand layers. Similarly, the rating could potentially be adjusted downward (to short) if laterally continuous sand layers were encountered at a shallow depth.

The indictor level ratings for both the landfill and the central operating area and incinerator are presented in Tables D2, and D3, Appendix D. In general, 'long' contaminant breakthrough times are preferred over 'variable' or 'short' breakthrough times because:

- the time available for contaminant degradation and interaction with the geologic materials is maximized;

- the slow rate of contaminant movement allows more time for the implementation of remedial measures should they be required; and

- if it is necessary to remove contaminated soils such as during the decommissioning of the central operating area, the slow rate of contaminant movement would result in a smaller volume of soil to be excavated.

Availability of alternative ground water supplies. In the event that local ground water resources are contaminated as a result of facility operations it would be necessary to provide local residents who rely on these resources, an alternative source of water supply. For purposes of this report an alternative supply is defined strictly as a communal well developed in an aquifer, which is either hydraulically isolated or physically distant from the impacted supply and as such is not likely to become contaminated. The two level scale, defined in Table 7, is used to differentiate sites in terms of the presence or absence of an alternative ground water. The indicator level ratings for the local siting options are presented in Table D4, Appendix D. Preference is expressed for siting a facility at a location for which alternative ground water supplies may potentially be available.

Existing ground water use and potential demand. A two level scale was developed to be used in the differentiation of sites based on the capability of the local aquifer(s) to accommodate water quantity and quality requirements imposed by such demanding users as communities and/or industries (Table 7). The indicator ratings for the various siting options are presented in Table D4, Appendix D.

'Limited' is applied to those sites where aquifer use appears to be limited primarily to meeting domestic requirements because of water quantity and/or quality considerations

For example, the Salina Formation, is used as a source of domestic water supply in the vicinity of LF-3C. Although this aquifer is productive and is capable of meeting communal and industrial quantity requirements, water quality is generally reported as sulphurous and of poor quality.

'Potential for Expansion' was applied to sites where the local aquifer(s) is considered to be capable of meeting both domestic and more demanding water use requirements. The aquifer(s) is generally reported as being productive and the water quality, as good.

3.2.5.3 Indicator aggregation

Following indicator screening and scaling, the remaining indicators within each factor were combined (aggregation) and a suitability rating index was developed for each factor. Aggregation of the hydrogeologic factors involved only a single step. This is because the two indicators within each of the two factors are considered by the hydrogeologic study team to be equal in importance. For certain other disciplines the aggregation process involved two steps:

(1) the initial ranking of indicators within each factor; and
(2) indicator aggregation.

A rating index, based on twelve levels of relative suitability was commonly employed by the site selection team. This index included six positive levels (+6 to +1) to reflect positive impacts or considerations, and six negative levels (-1 to -6) to reflect relative degrees of negative impacts.

From a hydrogeologic perspective, the siting of a treatment or disposal facility is expected to pose some degree of risk at any location. Consequently, only levels -1 to -6 were considered to be applicable. The various factor suitability levels used in comparison of siting options are defined in Table 8.

3.3 APPLICATION OF FACTORS FOR COMPARISON OF SITING OPTIONS

The comparison of siting options using the "Capability to Provide Natural Containment" and "Impact on Ground Water Use" factors involved a total of seven separate steps as shown in Figure 12. These steps are described in the following sections.

3.3.1 CAPABILITY TO PROVIDE NATURAL CONTAINMENT FACTOR

This factor was used to:

- provide a preliminary comparison of the siting options based on their potential to provide natural containment (Step 1);

- establish whether those sites with identified potential constraints (Factor Suitability Rating of -6, Table 8), provide a second level of protection of ground water resources (Steps 2 to 4); and

- reassess the natural containment potential of the siting options with identified potential constraints (Step 5).

TABLE 8
SUMMARY DEFINITIONS OF FACTOR SUITABILITY RATINGS

FACTOR	FACTOR LEVEL	INDICATOR	INDICATOR LEVEL	RATIONALE
Capability to Provide Natural Containment	Positive Levels			Not considered applicable; the siting of a facility is expected to pose some degree of risk at any location.
	Level (-1)	Predictability of Geologic Condition	Uniform	Least constrained; the direction and rate of contaminant movement are potentially predictable; long breakthrough times provide relatively high natural containment.
		Contaminant Breakthrough Time	Long	
	Level(-2) Level(-3) Level(-4)			These suitability ratings were not utilized; the sites are considered to be either relatively unconstrained or potentially constrained.
	Level(-5)	Predictability of Geologic Condition	Locally variable	Potentially constrained over portions of the site; some uncertainty respecting the direction and rate of contaminant movement.
		Contaminant Breakthrough Time	Variable	

TABLE 8 (cont'd.)

SUMMARY DEFINITIONS OF FACTOR SUITABILITY RATINGS

FACTOR	FACTOR LEVEL	INDICATOR	INDICATOR LEVEL	RATIONALE
Capability to Provide Natural Containment	Level(-6)	Predictability of Geologic Condition	Uniform or Variable	Potential constraint; rating is dominated by the thin confining layer which results in short breakthrough times and corresponding low natural containment.
		Contaminant Breakthrough Time	Short	
Impact on Ground Water Use	Positive Levels			Not considered applicable; siting of a facility is expected to pose some degree of risk at any location.
	Level(-1)	Availability of Alternative Ground Water Supplies	Yes	Least constrained; alternative ground water supplies are potentially available in the event the existing supply is contaminated; use of the local aquifer(s) is limited by water quantity or quality considerations to domestic and agricultural use.
		Existing Ground Water Use and Potential Demand	Limited	

TABLE 8 (cont'd.)

SUMMARY DEFINITIONS OF FACTOR SUITABILITY RATINGS

FACTOR	FACTOR LEVEL	INDICATOR	INDICATOR LEVEL	RATIONALE
Impact on Ground Water Use	Level(-2) Level(-3) Level(-4)			These suitability ratings were not utilized; in the event that the potential exists for impacting the existing source of supply, the suitability of the site for facility development would require considerations of the characteristics of the water resource impacted and the availability of alternative water supplies.
	Level(-5)	Availability of Alternative Ground Water Supplies	No	Impact on existing sources of supply may be considered to be significant if a suitable alternative ground water supply is not available.
		Existing Ground Water Use and Potential Demand	Limited	
	Level(-5)	Availability of Alternative Ground Water Supplies	Yes	Impact on existing sources of supply may be considered to be significant if the existing source of supply is capable of meeting more demanding water use requirements such as those of communities and industries.
		Existing Ground Water Use and Potential Demand	Potential for expansion	

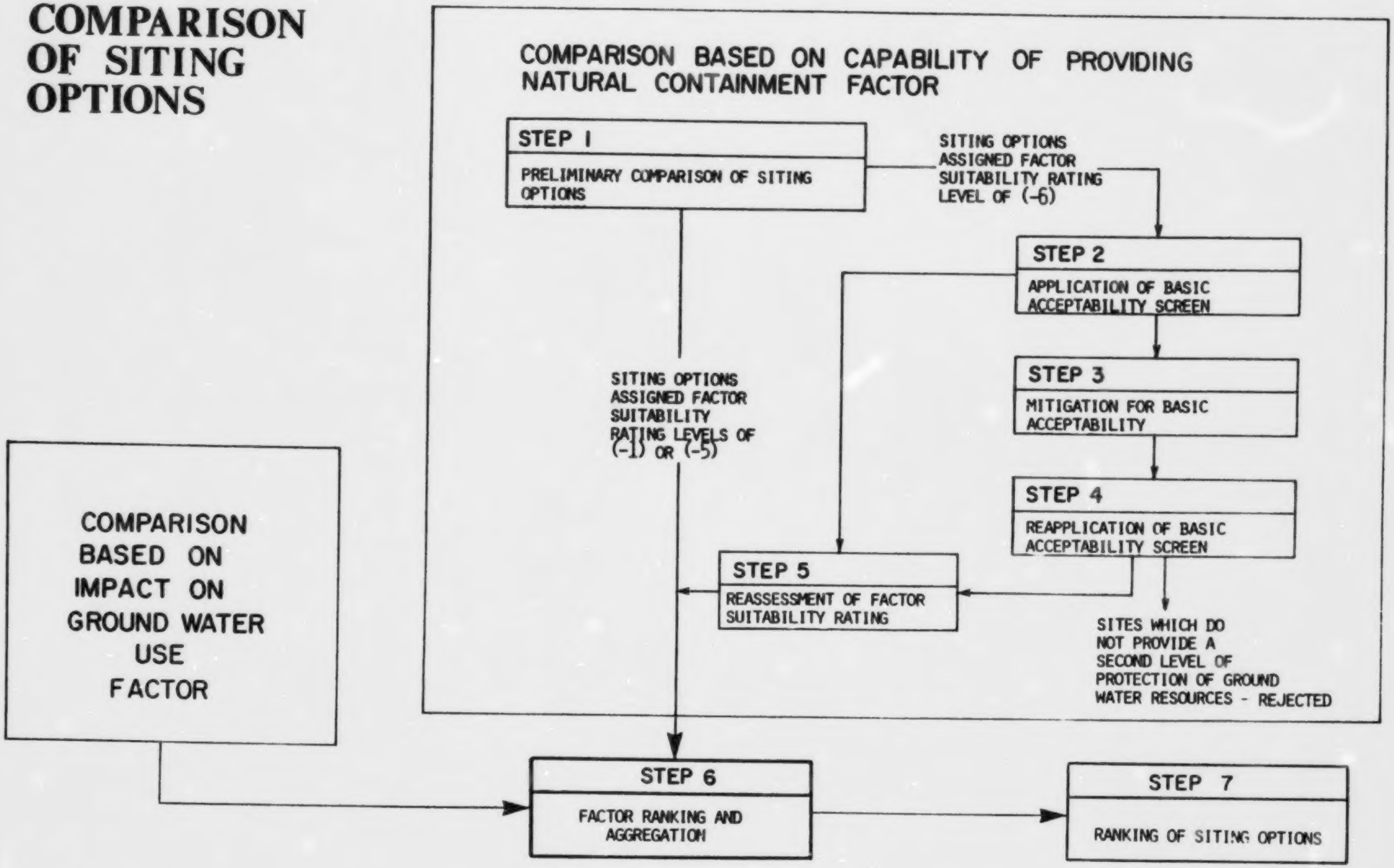
TABLE 8 (cont'd.)

SUMMARY DEFINITIONS OF FACTOR SUITABILITY RATINGS

FACTOR	FACTOR LEVEL	INDICATOR	INDICATOR LEVEL	RATIONALE
Impact on Ground Water Use	Level(-6)			Not applicable.

FIGURE 12

COMPARISON OF SITING OPTIONS


COMPARISON BASED ON CAPABILITY OF PROVIDING NATURAL CONTAINMENT FACTOR
STEP 1
PRELIMINARY COMPARISON OF SITING OPTIONS
SITING OPTIONS ASSIGNED FACTOR SUITABILITY RATING LEVEL OF (-6)
STEP 2
APPLICATION OF BASIC ACCEPTABILITY SCREEN
STEP 3
MITIGATION FOR BASIC ACCEPTABILITY
STEP 4
REAPPLICATION OF BASIC ACCEPTABILITY SCREEN
SITING OPTIONS ASSIGNED FACTOR SUITABILITY RATING LEVELS OF (-1) OR (-5)
STEP 5
REASSESSMENT OF FACTOR SUITABILITY RATING
SITES WHICH DO NOT PROVIDE A SECOND LEVEL OF PROTECTION OF GROUND WATER RESOURCES - REJECTED
COMPARISON BASED ON IMPACT ON GROUND WATER USE FACTOR
STEP 6
FACTOR RANKING AND AGGREGATION
STEP 7
RANKING OF SITING OPTIONS

Preliminary comparison of siting options (Step 1). The first step involved highlighting major differences in the options based on the extent to which the natural setting provides containment. The analysis discussed in greater detail in Appendix A, involved superimposing the facilities onto the hydrogeologic settings of the sites. Facility characteristics described in Section 1.4 particularly with reference to the contaminant release scenarios, facility layouts and proposed design specifications, were used in this analysis. Where necessary these designs were modified to accommodate site specific geotechnical considerations. For example, geotechnical considerations limit total landfill height at LF-3C and LF-9C and both landfill height and depth at LF-1E.

Table 9 presents the factor suitability ratings assigned to each of the eight siting options. Also provided are the indicator scaling levels used in this evaluation and the major reasons for assigning the indicator levels. Based on this comparison:

(1) Two siting options - LF-3C and LF-9C, were assigned a factor suitability rating of -1. The natural containment capability for these two siting options, as reflected in the long contaminant breakthrough times (results presented in Tables D2 and D3, Appendix D), are comparatively greater than for the other six options.

(2) Two siting options -LF-1E and LF-1E/PI-27E, are assigned a factor suitability rating of -5. Sand layers associated with local geologic features

TABLE 9

SUMMARY OF SUITABILITY RATING FOR "CAPABILITY OF PROVIDING NATURAL CONTAINMENT" FACTOR

SITING OPTIONS	FACTOR SUITABILITY	INDICATOR	INDICATOR LEVEL	RATIONALE
LF-3C	Level-1	Predictability of Geologic Condition Contaminant Breakthrough Time	Uniform Long	The confining layer is uniform and laterally and vertically continuous. Breakthrough time for both the landfill and the central operating area is anticipated to be long as a consequence of the thick, confining layer.
LF-9C	Level-1	Predictability of Geologic Condition Contaminant Breakthrough Time	Uniform Long	The confining layer is uniform and laterally and vertically continuous. Breakthrough time for both the landfill and the central operating area is anticipated to be long as a consequence of the thick, confining layer.
LF-1E	Level-5	Predictability of Geologic Condition	Locally Variable	Confining layer thins to extinction under southeastern portion of site as a result of a local morainal feature. Sand layers associated with the moraine could be present within the confining layer under the site.

TABLE 9 (cont'd)

SUMMARY OF SUITABILITY RATING FOR "CAPABILITY OF PROVIDING NATURAL CONTAINMENT" FACTOR

SITING OPTION	FACTOR SUITABILITY	INDICATOR	INDICATOR LEVEL	RATIONALE
LF-1E (cont'd)	Level-5	Contaminant Breakthrough Time	Variable	Breakthrough time anticipated to vary locally as a result of local variability in confining layer thickness.
LF-1E/ PI-27E	Level-5	Predictability of Geologic Condition	Locally Variable/ Locally Variable	Confining layer varies under both sites as a result of locally occurring geologic features: - LF-1E morainal feature to southeast, - PI-27E buried sand to northwest. Sand layers could be present within the confining layer under portions of both sites.
		Contaminant Breakthrough Time	Variable/ Variable	Breakthrough times are anticipated to vary locally at both sites as a result of variable confining layer thicknesses.
LF-2N/ PI-1N	Level-6	Predictability of Geologic Condition	Variable/ Uniform	Textural variability is noted within the confining layer at LF-2N. Such variability does not exist at PI-1N. The discontinuous confining layer at LF-2N and the thin confining layer at PI-1N is anticipated to result in rapid breakthrough times.
		Contaminant Breakthrough Time	Short/ Short	

TABLE 9 (cont'd)

SUMMARY OF SUITABILITY RATING FOR "CAPABILITY OF PROVIDING NATURAL CONTAINMENT" FACTOR

SITING OPTION	FACTOR SUITABILITY	INDICATOR	INDICATOR LEVEL	RATIONALE
LF-2N/ PI-13N	Level-6	Predictability of Geologic Conditions	Variable/ Locally Variable	Textural variability is noted within the confining layer at LF-2N. The confining layer at PI-13N is locally discontinuous as a result of erosion.
		Contaminant Break-through Time	Short/Short	The thin and discontinuous confining layer at both sites results in relatively rapid breakthrough times.
LF-4N/ PI-1N	Level-6	Predictability of Geologic Conditions	Uniform/ Uniform	The confining layer is uniform and laterally and vertically continuous at both sites.
		Contaminant Break-through Time	Short/Short	The confining layer is thin at both sites resulting in relatively rapid breakthrough times.
LF-4N/ PI-13N	Level-6	Predictability of Geologic Conditions	Uniform/ Locally Variable	The confining layer is uniform and laterally and vertically continuous at LF-4N. The confining layer at PI-13N is discontinuous as a result of erosion.

TABLE 9 (cont'd)

SUMMARY OF SUITABILITY RATING FOR "CAPABILITY OF PROVIDING NATURAL CONTAINMENT" FACTOR

SITING OPTION	FACTOR SUITABILITY	INDICATOR	INDICATOR LEVEL	RATIONALE
LF-4N/ PI-13N (cont'd)	Level-6	Contaminant Break-through Time	Short/Short	The confining layer is thin at both sites and discontinuous at PI-13N resulting in relatively rapid breakthrough times

could be present within the confining layer at these sites. The confining layer thickness and contaminant breakthrough time vary locally.

(3) The remaining four siting options - LF-2N/PI-1N, LF-2N/PI-13N, LF-4N/PI-1N and LF-4N/PI-13N were assigned a factor suitability rating of -6. These siting options are identified as being potentially constrained. The confining layer below these sites is either thin or locally absent, resulting in relatively rapid contaminant breakthrough time.

Application of basic acceptability screen (Step 2). Four sites - LF-2N, LF-4N, PI-1N and PI-13N were identified as being potentially constrained. This step involved the evaluation of these four sites to determine their basic acceptability, namely whether the identified constraints would preclude the use of any of these sites. From a hydrogeologic perspective, the failure of a site to provide a second level of protection of the environment, beyond that provided by safeguards built into the facility design and operations, is viewed as a basis for rejection of the site.

The basic acceptability screen involved distinguishing between the sites with potential constraints, to identify those sites which are, and are not, anticipated to provide a second level of protection. Proposed excavation depths for facilities, 10 m for the conventional landfill (5 m for LF-1E because of geotechnical considerations) and 8 m for the central operating area, (Section 1.4), were compared to the total confining layer thickness underlying the four sites

(LF-2N, LF-4N, PI-1N and PI-13N). Three sites LF-2N, PI-1N and PI-13N were identified as not providing a second level of protection. In other words, a 10 m deep excavation for a conventional landfill could be expected to locally penetrate the confining layer at LF-2N. Similarly, 8 m deep excavations as proposed for the central operating area would be expected to locally penetrate the confining layer at PI-1N and PI-13N. In both instances, leachate from the landfill and untreated wastes from the plant facilities (contaminant release scenarios - Section 1.4) could discharge directly into underlying aquifers without the benefits of attenuation afforded by the confining layer.

The confining layer at LF-4N would not be completely penetrated by a 10 m deep excavation and the site is considered to be capable of providing some natural containment. Site LF-4N was therefore carried forward to Step 5. Sites LF-2N, PI-1N and PI-13N were carried forward to Step 3.

Mitigation for basic acceptability (Step 3). Because the facility characteristics as described in Section 1.4 represent preliminary designs, it was considered reasonable to assess the effects of adjusting the facility design at LF-2N, PI-1N and PI-13N to maximize the potential for natural containment.

Step 3 essentially involved the introduction of shallower excavation depths and modified facility designs as a means whereby the penetration of the layer could be kept to a minimum. The following modifications were identified in conjunction with the engineering consultant, Monenco Limited:

Engineered Landfill:

- modified conventional landfill with excavation depths limited to 5 m;
- above ground landfill design option (no excavation).

Central Operating Area:

- excavation depths for the central operating area limited to 5 m (PI-1N and PI-13N).

It should be noted that the confining layer at the three sites (LF-2N, PI-1N and PI-13N) for which mitigation was introduced, is fractured over its upper 5 m (see technical appendices). The upper 5 m portion of the confining layer can be expected to provide only minimal containment with respect to vertical contaminant movement. Therefore, if the upper 5 m of the confining layers are discounted, the two identified landfill design alternatives - modified conventional and above ground, would provide equivalent natural containment. Similarly, little additional benefit is gained by introducing a shallower maximum excavation depth (less than 5 m) in the central operating area.

Reapplication of basic acceptability screen (Step 4). The basic acceptability screen was reapplied to the three sites for which the facilities characteristics were modified. As a result of this screen LF-2N initially, and PI-13N subsequently, are identified as not providing a second level of protection. The lower part of the confining layer at LF-2N displays lateral and vertical textural variability which results in some uncertainty in the interpretation of confining layer thickness. Even with the above ground design, leachate could be expected to enter the underlying aquifer without the benefits of attenuation afforded by the confining layer. A more detailed discussion of the application of basic acceptability screen at LF-2N is contained in an Interim Report titled Site Selection Process Phase 4A: Selection of a Preferred Site(s), Interim Site Selection Report, Candidate Site LF-2N (M.M. Dillon Limited, 1985c).

The confining layer at PI-13N is generally less than 5 m in thickness and displays some local variability. The shallower 5 m excavation depth for the plant facilities would be expected to locally penetrate the confining layer.

A 5 m excavation for plant facilities at PI-1N would not completely penetrate the confining layer. This site would therefore be capable of providing some natural containment. Consequently, PI-1N was carried forward to Step 5. Siting options including LF-2N and PI-13N, were not carried forward into Step 5 and were not ranked (Step 7).

Reassessment of factor suitability rating (Step 5). Two sites, LF-4N which passed the basic acceptability screen without mitigation and PI-1N with mitigation, were carried forward in the process to Step 5. Step 5 involved the reassessment of the factor suitability rating level assigned to the one remaining site option which includes these two sites. The initial -6 level assigned to these options, as defined in Table 8 and presented in Table 9, is still considered to be applicable. The relatively rapid contaminant breakthrough times determined for these two sites are an identified constraint to facility development.

3.3.2 IMPACT ON GROUND WATER USE FACTOR

Table 10 presents the relative suitability ratings assigned to each of the eight siting options for the 'Impact on Ground Water Use' factor. Also provided are the indicator scaling levels used in the evaulation and the major reasons for assigning the indicator levels. This factor was introduced to provide a qualitative assessment of the relative importance of local ground water resources in the event that facility operations result in some degradation of the resource. Facility characteristics do not influence the factor suitability ratings identified on Table 10.

3.4 FACTOR AGGREGATION AND RANKING

The ranking of the siting options combines considerations specific to:

- the extent to which the hydrogeologic setting provides natural containment of contaminants which may potentially be released at the proposed OWMC facilities (accommodated by the 'Capability of Providing Natural Containment' factor); and

- the characteristics of the ground water resources in the site vicinity potentially affected by contaminants and alternatives to these resources (accommodated by the 'Impact on Ground Water Use' factor).

To facilitate ranking of the siting options it was initially necessary to establish the relative importance of each of the two factors.

TABLE 10

SUMMARY OF SUITABILITY RATING FOR "IMPACT ON GROUND WATER USE" FACTOR

SITING OPTION	FACTOR SUITABILITY	INDICATOR	INDICATOR LEVEL	RATIONALE
LF-3C	Level-1	Availability of Alternative Ground Water Supplies	Yes	Ground water supplies may be developed to the north in the Guelph Formation aquifer.
		Existing Ground water use and Potential Demand	Limited	Aquifer use is limited primarily to domestic and agricultural requirements.
LF-9C	Level-5	Availability of Alternative Ground Water Supplies	Yes	Ground water supplies may be developed in the Guelph Formation aquifer sufficiently removed from the site to be unaffected.
		Existing Ground water use and Potential Demand	Potential for Expansion	Aquifer may be capable of meeting more demanding water use requirements.
LF-1E	Level-5	Availability of Alternative Ground Water Supplies	Yes	Ground water supplies may be developed in either the Guelph Formation or shallow granular aquifers sufficiently removed from the site to be unaffected.

TABLE 10 (cont'd.)

SUMMARY OF SUITABILITY RATING FOR "IMPACT ON GROUND WATER USE" FACTOR

SITING OPTION	FACTOR SUITABILITY	INDICATOR	INDICATOR LEVEL	RATIONALE
LF-1E (cont'd.)		Existing Ground water use and Potential Demand	Potential for Expansion	Aquifer may be capable of meeting more stringent water use requirements.
LF-1E/ PI-27E	Level-5	Availability of Alternative Ground Water Supplies	Yes for both sites	Ground water supplies may be developed in either the Guelph Formation or shallow granular aquifers sufficiently removed from the site to be unaffected.
		Existing Ground Water Use and Potential Demand	Potential for Expansion at both sites	Aquifer may be capable of meeting more stringent water use requirements.
LF-2N/ PI-1N	Level-5	Availability of Alternative Ground Water Supplies	Yes for both sites	Ground water supplies may be developed in shallow granular aquifers sufficiently removed from the sites to be unaffected.
		Existing Ground water use and Potential Demand	Potential for Expansion/ Limited	Aquifers at LF-2N may be capable of meeting more demanding water use requirements. Aquifer use at PI-1N is limited primarily to domestic and agricultural requirements.

TABLE 10 (cont'd.)

SUMMARY OF SUITABILITY RATING FOR "IMPACT ON GROUND WATER USE" FACTOR

SITING OPTION	FACTOR SUITABILITY	INDICATOR	INDICATOR LEVEL	RATIONALE
LF-2N/ PI-13N	Level-5	Availability of Alternative Ground Water Supplies	Yes/No	Ground water supplies may be developed in granular aquifers sufficiently removed from LF-2N to be unaffected. The suitability rating reflects the absence of a suitable alternative source of ground water supply in the vicinity of PI-13N.
		Existing Ground Water Use and Potential Demand	Potential for Expansion/ Limited	Aquifers at LF-2N may be capable of meeting more demanding water use requirements. Aquifer use at PI-13N is limited primarily to domestic and agricultural requirements.
LF-4N/ PI-1N	Level-5	Availability of Alternative Ground Water Supplies	Yes for both sites	Ground water supplies may be developed in granular aquifers sufficiently removed from the sites to be unaffected.
		Existing Ground Water Use and Potential Demand	Potential for Expansion/ Limited	Aquifer at LF-4N may be capable of meeting more demanding water use requirements. Aquifer use at PI-1N is limited primarily to domestic and agricultural requirements.

TABLE 10 (cont'd.)

SUMMARY OF SUITABILITY RATING FOR "IMPACT ON GROUND WATER USE" FACTOR

SITING OPTION	FACTOR SUITABILITY	INDICATOR	INDICATOR LEVEL	RATIONALE
LF-4N/ PI-13N	Level-5	Availability of Alternative Ground Water Supplies	Yes/No	The suitability rating reflects the absence of a suitable alternative source of ground water supply in the vicinity of PI-13N. Alternative supplies are available in the vicinity of LF-4N.
		Existing Ground Water Use and Potential Demand	Potential for Expansion/ Limited	Aquifer at LF-4N may be capable of meeting more demanding water use requirements. Aquifer use at PI-13N is limited to domestic and agricultural requirements.

As discussed in Section 1.4 the composition and toxicity of potential contaminants cannot be fully anticipated. Some contaminants from the facilities are therefore assumed to represent a health and/or environmental concern. Release of these contaminants directly to an aquifer could result in the unacceptable degradation of the resource.

In ranking of the options, emphasis was therefore placed on the natural containment potential of the sites. The 'Impact on Ground Water Use' factor was considered to be less important and was used only to differentiate amongst those options which are considered to provide similar natural containment.

3.5 RANKING OF SITING OPTIONS

Only six sites, representing five siting options, passed the basic acceptability screen and were carried forward to Step 7. Table 11 presents the ranking for the remaining five siting options based on the factor suitability ratings. A discussion of the rankings is provided in the following summary.

LF-3C and LF-9C are the two highest ranked siting options. The silt-clay confining layer below these sites is laterally continuous and is relatively uniform in thickness, ranging from about 23 to 31 m at LF-3C and about 30 to 35 m at LF-9C. Contaminant breakthrough times (in years) for these two sites are shown in Table 12. Geotechnical considerations limit the landfill height (conventional design) for both sites to 4 m.

Table 11
Ranking Of The Siting Options

SITING OPTION	FACTOR SIUTABILITY RATING LEVELS		
	CAPABILITY TO PROVIDE NATURAL CONTAINMENT	IMPACT ON GROUND WATER USE	RANKING
LF-3C	-1	-1	1
LF-9C	-1	-5	2
LF-1E	-5	-5	3
LF-1E/ PI-27E	-5	-5	3
LF-4N/ PI-1N	-6	-5	5

TABLE 12 CONTAMINANT BREAKTHROUGH TIMES, LF-3C AND LF-9C*

FACILITY	CONTAMINANT BREAKTHROUGH TIME (years) LF-3C	LF-9C
Conventional Landfill (10 m deep excavation)	600-1900	1200-1700
Central Operating Area		
• spill residual at surface	5200	4000
• leak at 8 m below surface	4300	3400

* Table condensed from Tables A3 and A5, Appendix A.

These siting options are expected to provide relatively greater natural containment of potential contaminants than that provided at the other three options.

These two siting options are differentiated mainly on the basis of the water supply potential of the underlying aquifers. Water supplies at LF-3C are developed primarily in the Salina and Guelph formations. Water supplies completed in the Salina Formation commonly experience quality related problems. This appears to be the case at LF-3C. Use of the underlying aquifer is therefore limited as a result of water quality considerations primarily to domestic and agricultural requirements. Water supplies at LF-9C, on the other hand, are developed primarily in the Guelph Formation. This aquifer is capable of meeting more stringent communal and/or industrial water requirements and has greater potential for future water supply expansion. LF-3C is therefore ranked slightly ahead of LF-9C in preference. Nevertheless, both sites have a thick, uniform confining layer overlying the aquifers.

Siting Options LF-1E, and LF-1E in combination with PI-27E, share the third position in the overall ranking of the options. LF-1E is underlain by a silty-clay confining layer which varies locally from 0 to about 27 m in thickness. This variability is attributed to the presence of shallow sand layers associated with a morainal feature, locally known as 'Walnut Hill'. Contaminant breakthrough times at LF-1E are expected to vary appreciably across the site. The following breakthrough times (Table 13) assume that the facility layout can avoid the shallow sand layers.

TABLE 13 CONTAMINANT BREAKTHROUGH TIMES, LF-1E*

FACILITY	CONTAMINANT BREAKTHROUGH TIME (YEARS)
Conventional landfill (5 m deep excavation)	750-2500
Central Operating Area	
• spill residue at surface	1200-2600
• leak at 8 m below surface	830-2200

* Table condensed from Tables A3 and A5, Appendix A.

Geotechnical constraints have been identified at LF-1E which could potentially limit:

- the maximum excavation depth for the proposed landfill to 5 m; and

- the total thickness of the landfill to 1 1/2 times the excavated depth.

The basis for these constraints is discussed in detail in the LF-1E technical appendix report. Geotechnical information was provided to Monenco Limited and used in their determination of site landfilling capacity (Monenco Limited 1985b). Contaminant breakthrough times presented in Table 13 are based on a modified conventional landfill design which accommodates these constraints, namely, 5 m depth limitation and a total height above ground of 2.5 m (Appendix A). The geotechnical constraints are not expected to limit excavation depths for the proposed central operating area. Construction methods are available which would mitigate these constraints.

PI-27E is also underlain by a silt-clay confining layer, the thickness of which varies locally from about 6 m to 26 m, as a result of buried sand deposits. The buried sand is present mainly under the northwestern portion of the site. Thin sand lenses which appear to be limited in extent were also found within the confining layer in the central portion of this site. The confining layer appears to be more uniform to the southeast. Contaminant breakthrough times for the central operating area, to be located in the southeast portion of the site, are listed in Table 14.

TABLE 14 CONTAMINANT BREAKTHROUGH TIMES, PI-27E*

LEAK SCENARIOS	CONTAMINANT BREAKTHROUGH TIME (YEARS)
• spill residual at surface	2600
• subsurface leak at 8 m below surface	2000

* Table condensed from Table A5, Appendix A.

Ground water supplies in the vicinity of LF-1E are developed in the bedrock (Salina and Guelph Formations) and in basal granular deposits immediately above the bedrock. In the vicinity of PI-27E supplies are developed in the Guelph Formation and the basal granular.

No discernible differences have been identified at these sites in terms of water supply potential. The aquifers under both sites appear to have the potential of meeting more stringent water use requirements such as communal and industrial.

Differences between these two options LF-1E and LF-1E/PI-27E are attributed specifically to the advantages and disadvantages associated with fully versus partially integrated siting options. With respect to a fully integrated option all contaminant sources are located on one site. It is therefore not necessary to duplicate perimeter monitoring systems and contaminant contingency measures. On the other hand, a partially integrated option provides greater flexibility in siting facilities because of the larger land area. This flexibility is particularly significant where hydrogeologic constraints which could exclude development over portions of a site may be present. The partially integrated option also allows for greater landfill site life.

Siting option LF-4N in combination with PI-1N is the least preferred of the five options and has been ranked fifth. LF-4N is underlain by a clayey silt to silt till confining layer which ranges in thickness from about 8 to 19 m. CONfining layer thickness below the proposed landfill ranges from about 11 to 18 m. Thickness variations are attributed to the presence of a buried bedrock valley trending east-west through the site. The confining layer thins along the flanks of the valley and thickens over the centre of the valley. Contaminant breakthrough times calculated for a 10 m deep conventional landfill design vary from about 1 to 68 years.

LF-4N is underlain by two sand layers which have aquifer potential and appear to have off-site continuity. The upper layer is relatively thin (up to about 3 m in thickness) but appears to be capable of sustaining domestic supplies. The lower sand layer overlies the bedrock and may locally be upwards of 8 to 10 m thick. This basal sand layer is potentially capable of meeting more stringent water supply requirements such as communal or industrial needs.

PI-1N is underlain by a confining layer which is made up of two tills, an upper silt-clayey silt till and the upper fine textured portion of the underlying clayey silt to silty sand till. The total confining layer thickness ranges from 7 to 15 m. Thickness variations are attributed to sand layers present within the lower of the two tills. In application of the basic acceptability screen, the proposed excavation depth of 8 m for the incineration/treatment plant was modified to 5 m. This modification was based strictly on observed geologic variability over the entire acquisition area and not only on confining layer thickness below the proposed plant location which averages about 10 m. The contaminant breakthrough times based on this average value of 10 m are presented in Table 15.

TABLE 15 CONTAMINANT BREAKTHROUGH TIMES, PI-1N*

LEAK SCENARIOS	CONTAMINANT BREAKTHROUGH TIME (YEARS)
• Spill residual at surface	29
• Subsurface leak at 8 m below surface	28

* Table condensed from Table A5, Appendix A.

water supplies in the vicinity of PI-1N are developed in the Queenston Formation and in sand layers within the overburden. Well yields are generally low and aquifer use is limited primarily to domestic and agricultural requirements.

The ranking of the LF-4N/PI-1N siting option reflects the thin confining layer and correspondingly rapid contaminant breakthrough times at both sites.

3.6 CONSIDERATIONS FOR ENHANCING SITE SUITABILITY

The natural containment potential of the individual sites may be enhanced through consideration of alternative landfill designs and/or readjustments to facility placement. These alternative designs and adjustments to facility placement should be considered during Phase 4B when more detailed information on the preferred site(s) becomes available.

3.6.1 ALTERNATIVE LANDFILL DESIGN CONSIDERATIONS

Three general landfill design alternatives have been identified in the OWMC report titled Facilities Development Process, Phase 3 Report (1984) for more detailed study:

- conventional landfill;
- above ground landfill; and
- shallow entombed landfill.

A general discussion of design features is provided in Monenco Limited, (1985a). The conventional design concept provides the greatest landfill capacity for a given area. The capacity of the above ground and shallow entombed landfills for a given area is reduced.

The site-by-site comparison of the three landfill designs, based on contaminant breakthrough times, is presented in Appendix A. The location and dimensions of the landfills were adjusted to accommodate site specific hydrogeologic and geotechnical considerations. Design alternatives considered for each of the four landfill sites are listed in Table 16.

As discussed in Section 3.5, height and/or depth restrictions were imposed at LF-3C, LF-9C and LF-1E as a result of geotechnical constraints. Geotechnical depth restrictions at LF-1E also rule out the potential use of the shallow entombed alternative at this site. The shallow entombed alternative was also not considered at LF-4N. Excavations of the necessary depth for this alternative at LF-4N would intersect the aquifer over portions of the site and violate the basic acceptability requirement.

TABLE 16 SITES WHICH CAN POTENTIALLY ACCOMMODATE THE VARIOUS LANDFILL DESIGN ALTERNATIVES

SITE	CONVENTIONAL LANDFILL	SHALLOW ENTOMBED LANDFILL	ABOVE-GROUND LANDFILL
LF-3C	X*	X	X
LF-9C	X*	X	X
LF-1E	X*		X
LF-4N	X		X

* Height and/or depth restrictions imposed as a result of geotechnical constraints.

The contaminant breakthrough times presented in Table A3, Appendix A, for the various landfill design alternatives, are well within the time ranges determined to account for natural onsite geologic variability (Table A2, Appendix A). It is therefore suggested that all design alternatives be retained until detailed site specific engineering feasibility studies can be undertaken during Phase 4B.

3.6.2 ADJUSTMENTS TO FACILITY PLACEMENT

The contaminant containment potential at the individual sites may be enhanced by the judicious placement of facilities on those portions of the sites with the greatest confining layer thickness, where possible. The range in contaminant breakthrough times calculated for LF-4N for example, could be narrowed from 1 to 68 years (for the entire site) to about 45 to 68 years by limiting development to just those portions of the site where the confining layer thickness exceeds 15 m. Benefits accrued by the selective placement of facilities should be established during Phase 4B following the collection of additional hydrogeologic data on the preferred site(s).

4.0 CONCLUSIONS AND RECOMMENDATIONS

The geologic, hydrogeologic and geotechnical considerations specific to the development of the individual candidate sites for an OWMC facility are documented in this report and the accompanying technical appendices.

An analysis of the basic acceptability of the eight sites resulted in the identification of two sites, LF-2N and PI-13N, as not providing a second level of protection. These sites were subsequently dropped from the hydrogeologic comparison of siting options.

The final comparison of siting options was limited to five options (representing six sites). The siting options were ranked from the most preferred to least preferred as follows:

LF-3C
LF-9C

LF-1E and LF-1E/PI-27E (ranked equal)

LF-4N/PI-1N

LF-3C and LF-9C, the highest ranked siting options are both underlain by a thick, uniform confining layer. These two siting options also provide the greatest flexibility from a hydrogeologic perspective in being able to accommodate all the alternative landfill design concepts currently under consideration. Siting options LF-1E and LF-1E in combination with PI-27E are underlain by a confining layer which varies locally in thickness and may contain sand layers with offsite continuity. These sand layers may act as pathways for offsite migration of contaminants. LF-1E also appears to be the most constrained geotechnically, and is only able to accommodate landfill designs for which excavations are limited to 5 m.

Siting option LF-4N/PI-1N is the least preferred of the options because of the thin confining layer underlying these sites. Contaminant breakthrough is anticipated to be relatively rapid in comparison to that of the other options. LF-4N is also not able to accommodate the shallow entombed landfill design alternative. Excavations of necessary depth for this alternative would locally intersect the underlying aquifer.

A number of more detailed hydrogeologic assessments will be required during Phase 4B on the preferred site(s) and site(s) vicinity.

- A hydrogeologic assessment should be carried out along the regional and local access routes. This assessment should inventory ground water use and identify the sensitivity of this use to potential spills. The purpose of this assessment would be to serve as a guide for mitigating potential spills.

- A hydrogeologic assessment should be undertaken on and in the proximity of the preferred site(s). The purpose of this assessment would be to confirm the site setting as predicted in this report. In addition, hydrogeologic design parameters would be provided to the design engineers to ensure that the conceptual site design and operations is compatible with the hydrogeologic setting.

- A geotechnical assessment should be undertaken to assist in the conceptual foundation design of the various facilities. In this regard liaison with the design engineers will be required. This assessment should be integrated with the hydrogeologic studies to optimize use of field and laboratory testing.
- A ground water monitoring program should be designed to serve as an early warning mechanism in the event of unpredicted contaminant movement.
- Contingency plans should be formulated, in conjunction with the design engineers, to act as back up in the event that the monitoring system identifies a need.

5.0 REFERENCES

Carslaw, H.S., J.C. Jaeger
1959: Conduction of Heat in Solids; 2nd Edition Oxford University Press, 510 pp.

Cherry, J.A., R.W. Gillham, J.F. Barker
1984: Contaminants in Groundwater: Chemical Processes. Groundwater Contamination (Studies in Geophysics); National Academy Press, Washington, DC, pp. 46-64.

Cherry, J.A.
1985: Personal communications, research status.

Cleary, R.W., M.J. Ungs
1978: Analytical Models for Groundwater Pollution and Hydrology; Princeton University Water Resources Report No. 78-WR-15.

M.M. Dillon Limited
1984: Site Selection Process, Phase 3B: Selection of Candidate Sites;
Volume 1 - General Characteristics and the Identification of Site Areas, 85 p. and Appendices.
Volume 2 - Identification of Potential Sites, 75 p. and Appendices.
Volume 3 - Identification of Candidate Sites, 158 p. and Appendices.
Reports prepared for the Ontario Waste Management Corporation, December 1984.

....
1985a: Site Selection Process, Phase 4A: Selection of a Preferred Site(s) - Site Selection; Report prepared for the Ontario Waste Management Corporation, 1985.

....
1985b: Site Selection Process, Phase 4A: Selection of a Preferred Site(s) - Transportation; Report prepared for the Ontario Waste Management Corporation, 1985.

M.M. Dillon Limited
1985c: Site Selection Process, Phase 4A: Selection of a Preferred Site(s) - Interim Site Selection Report, Candidate Site LF-2N; Report prepared for the Ontario Waste Management Corporation, May 1985.

Freeze, R.A., J.A. Cherry
1979: Groundwater; Prentice-Hall, Englewood Cliffs, N.J., 604 pp.

Gartner Lee Associates Limited
1982a: Primary Environmental Information, Part 1, Geological/Hydrogeological Inventory; Report prepared for Ontario Waste Management Corporation, August 1982, 20 p.

....
1982b: Primary Environmental Information, Geological/Hydrogeological Inventory, Appendix, Data Resource Sheets, Volumes 1 and 2; Report prepared for Ontario Waste Management Corporation, October 1982.

....
1983: Hydrogeological Considerations for Facilities Siting; Report prepared for Ontario Waste Management Corporation, May 1983.

....
1984a: Geologic and Hydrogeologic Inventory of the Golden Horseshoe Candidate Region; Report in draft prepared for Ontario Waste Management Corporation, March 1984, 48 p. and Appendices.

....
1984b: Site Selection Process, Phase 3B: Selection of Candidate Sites, Physical Resources; Report prepared for Ontario Waste Management Corporation, October 1984, 107 p. and Appendices.

....
1985: Site Selection Process, Phase 4A; Selection of a Preferred Site(s) - Surface Water Considerations; Report prepared for the Ontario Waste Management Corporation, 1985.

Gillham, R.W., J.A. Cherry
1982: Contaminant Migration in Saturated Unconsolidated Geologic Deposits; Geologic Society of America Special Paper 189, pp. 31-62.

Hildebrand, F.B.
1976: Advanced Calculus for Applications; Prentice-Hall, Englewood Cliffs, N.J. 646 pp.

Mackay, D.M., P.V.Roberts, J.A. Cherry
1985: Transport of Organic Contaminants in Groundwater; Environmental Science and Technology, Vol. 19, no. 5, pp. 384-392.

Monenco Limited
1985a: Status Report, Facility Design; Report prepared for the Ontario Waste Management Corporation. April 1985.

....
1985b: Site Selection Process, Phase 4A, Selection of a Preferred Site(s) - Engineering; Report prepared for the Ontario Waste Management Corporation, 1985.

Ogata, A., R.B.Banks,
1961: A solution of the differential equation of longitudinal dispersion in porous media; U.S. Geological Survey Professional Paper 411-A.

Ontario Ministry of the Environment
1984: The Incorporation of the Reasonable Use Concept Into the Ground Water Management Activities of the Ministry of the Environment; Draft document, July 1984.

Ontario Waste Management Corporation
1982a: Facilities Development Process, Phase I Report; September 1982, 42 pp.

Ontario Waste Management Corporation
1983a: Facilities Development Process, Phase 2 Report; January 1983, 58 pp.

....
1983b: Facilities Development Process, Phase 3 Interim Report; May 1983, 42 p.

....
1983c: Map Portfolio, Phase 3 Interim Report; May 1983, 10 maps.

....
1984: Facilities Development Process, Phase 3 Report; March 1984, 95 p.

....
1985: Background Material For The OWMC Phase 4A: Site Selection Workshops, Volume 1; May 1985, 14 p. and appendices.

Sudicky, E.A., J.A. Cherry, E.O. Frind
1983: Migration of Contaminants in Groundwater at a Landfill: A Case Study - 4. A Natural-gradient Dispersion Test; Journal of Hydrology, 63, pp. 81-108.

AGENCY AND PUBLIC CONTACTS

PROVINCIAL GOVERNMENT AGENCIES/CORPORATIONS

- Ontario Ministry of the Environment
  - Waste Management Branch, Toronto
  - Waste Resources Branch, Toronto
  - Central Region, Toronto Office
  - West Central Region, Hamilton Office
  - Welland District Office
- Ministry of Natural Resources
  - Ontario Geological Survey, Toronto
  - Petroleum Resources Branch, London
  - Niagara District Office, Fonthill
  - Cambridge District office, Cambridge
- Ministry of Transportation and Communications
  - Highway Engineering Division, Toronto
  - Engineering and Right-of-Way Office, Toronto
  - Fonthill Office
  - District 4, Burlington Office
  - District 6, Willowdale Office
- Ontario Hydro
- Ontario Land Corporation
- St. Lawrence Seaway Commission
- Niagara Escarpment Commission

MUNICIPALITIES

- Regional Municipality of Peel
- City of Mississauga
- Regional Municipality of Halton
- Town of Milton
- Regional Municipality of Niagara
- Township of West Lincoln
- City of Niagara Falls

CORPORATIONS

- Bell Canada
- C.N. Rail
- Interprovincial PipeLines
- Union Gas
- Grimsby Gas
- Provincial Gas
- Mr. H. Price (Private Gas Syndicate)

PUBLIC INTEREST GROUPS (THE GROUP OF EIGHT)

- Canadians for a Clean Environment
- Niagarans Against Toxins
- West Lincoln Task Force Against Toxic Waste
- Chippewa Watershed Association
- Tremaine-Britannia Group
- Omagh United Taxpayers
- Milton Environmental Advisory Group
- Mississauga Citizens Environmental Protection Association

CONSULTANTS

- Golder Associates
- Morrison Beatty Limited
- Hydrology Consultants
- Geological Testing Consultants (GTC)
- Terraprobe Limited

- Terraqua Investigations Ltd.
- Walker, Wright, Young Associates Ltd.

CONSERVATION AUTHORITIES

- Halton Region Conservation Authority
- Niagara Region Conservation Authority
- Metropolitan Toronto and Region Conservation Authority

APPENDICES

APPENDIX A - ASSESSMENT OF CONTAMINANT MOVEMENT THROUGH THE CONFINING LAYER

APPENDIX B - OWMC PHASE 4A FACTORS FOR SITE SELECTION

APPENDIX C - BASE MAPS SHOWING REFINED BOUNDARIES, ACCESS ROAD OPTIONS AND RAIL ACCESS OPTIONS

APPENDIX D - DATA MATRICES

APPENDIX A

ASSESSMENT OF CONTAMINANT MOVEMENT THROUGH THE CONFINING LAYER

APPENDIX A

TABLE OF CONTENTS

PAGE

A1.0 INTRODUCTION A-1

A2.0 BACKGROUND A-2

A2.1 METHODOLOGY A-2
A2.2 FACILITY AND SITE CHARACTERISTICS A-2
A2.2.1 GEOLOGY, HYDROGEOLOGY, AND GEOTECHNICAL CONDITIONS A-2
A2.2.2 LAYOUT A-7
A2.2.3 INCINERATION AND PHYSICAL/CHEMICAL TREATMENT PLANTS A-7
A2.2.4 ENGINEERED LANDFILL A-9
A2.2.5 CONTAMINANT CHARACTERISTICS A-10

A2.3 CALCULATIONS A-11
A2.4 LIMITATIONS A-14
A2.4.1 LIMITATIONS RELATED TO MODELLING ASSUMPTIONS A-15
A2.4.2 LIMITATIONS RELATED TO INPUT PARAMETERS A-17
A2.4.3 SUMMARY A-19

A3.0 POTENTIAL IMPACTS A-20

A3.1 LANDFILLS A-20
A3.2 CENTRAL OPERATING AREA A-24

A4.0 SUPPORTING INFORMATION A-28

A4.1 INPUT PARAMETER SENSITIVITY STUDY A-28
A4.2 MODEL DETAILS A-31
A4.2.1 "HEADROP" MODEL A-31
A4.2.2 "ONE-D" MODEL A-35
A4.2.3 "BLOKSOURCE" MODEL A-41
A4.2.4 "PATSOURCE" MODEL A-48

Note on Significant Figures: Two significant figures have been used throughout this appendix in reporting numerical results of calculations. This has been done for consistency and convenience, but does not necessarily reflect a calculated degree of accuracy for the values.

FIGURES

		PAGE
A1	METHODOLOGY FOR THE ASSESSMENT OF CONTAMINANT MOVEMENT THROUGH THE CONFINING LAYER	A-3
A2	EXAMPLE OF SUPERIMPOSING FACILITIES ON CANDIDATE SITE LF-9C	A-4
A3	EXAMPLE OUTPUT FOR A ONE-DIMENSIONAL CONTAMINANT TRANSPORT SOLUTION	A-40
A4	EXAMPLE OUTPUT FOR AN INSTANTANEOUS BLOCK CONTAMINANT SOURCE SOLUTION	A-47
A5	EXAMPLE OUTPUT FOR A THREE-DIMENSIONAL CONTAMINANT TRANSPORT SOLUTION	A-53

TABLES

		PAGE
A1	SHALLOWEST AQUIFERS ASSUMED FOR GROUND WATER PATHWAY ANALYSIS	A-6
A2	SUMMARY OF CONTAMINANT TRANSPORT MODELLING RESULTS - CONVENTIONAL LANDFILL	A-21
A3	SUMMARY OF CONTAMINANT TRANSPORT MODELLING RESULTS - SITE ADAPTED LANDFILLS	A-23
A4	SUMMARY OF CONTAMINANT TRANSPORT MODELLING RESULTS - ADAPTED CONVENTIONAL LANDFILL AT LF-4N - MITIGATION FOR HYDROGEOLOGIC CONSTRAINTS	A-25
A5	SUMMARY OF CONTAMINANT TRANSPORT MODELLING RESULTS - CENTRAL OPERATING AREA	A-26
A6	SENSITIVITY STUDY FOR LF-9C, CONVENTIONAL LANDFILL * - NORTHEASTERN PART OF SITE	A-29
A7	SENSITIVITY STUDY FOR PI-1N SPILL RESIDUAL SCENARIO	A-30

A1.0 INTRODUCTION

This appendix documents the hydrogeologic assessment of potential contaminant movement through the confining layer for each OWMC candidate site. The primary purpose of this appendix is to support the comparison study, but some of the information is applicable to conceptual engineering design.

This analysis is limited to a review of the pathways which could result in contaminants migrating off site in the ground water system. Hydrogeologic modelling was used extensively. The methodologies are described in this appendix. It is important to note, however, that the results should be interpreted in a comparative sense only, as the facility characteristics and relevant hydrogeologic parameters are preliminary and interpretive. A discussion of the limitations of the calculations is also included. A more comprehensive and definitive analysis is recommended for the Phase 4B investigation at the preferred site(s).

A2.0 BACKGROUND

A2.1 METHODOLOGY

Figure A.1 is a flow chart representing the general methodology used in the analysis. Also shown are section numbers indicating the structure and organization of the discussions in this appendix.

A2.2 FACILITY AND SITE CHARACTERISTICS

A2.2.1 GEOLOGY, HYDROGEOLOGY, AND GEOTECHNICAL CONDITIONS

The geologic, hydrogeologic, and geotechnical conditions at each of the candidate sites are described in the individual Technical Appendices for LF-3C, LF-9C, LF-1E, PI-27E, LF-2N, LF-4N, PI-1N, and PI-13N. Included in each appendix are geologic cross-sections showing stratigraphic interpretations based on Phase 4A drilling data (identified as Figures 5 and 6 in each technical appendix). Predictive assessments of contaminant transport impacts were undertaken by superimposing the facility design characteristics onto these cross-sections. An example of this superimposition approach is shown in Figure A2. Physical parameters used in this analysis, such as hydraulic gradients, porosities, hydraulic conductivities, and thicknesses, were extracted from the technical appendices.

The candidate sites are underlain by overburden consisting primarily of till and glaciolacustrine deposits. A confining layer has been defined at each site extending downward from the surface. It includes fine-textured materials, characterized by low hydraulic conductivity, which

FIGURE A1 METHODOLOGY FOR THE ASSESSMENT OF CONTAMINANT MOVEMENT THROUGH THE CONFINING LAYER

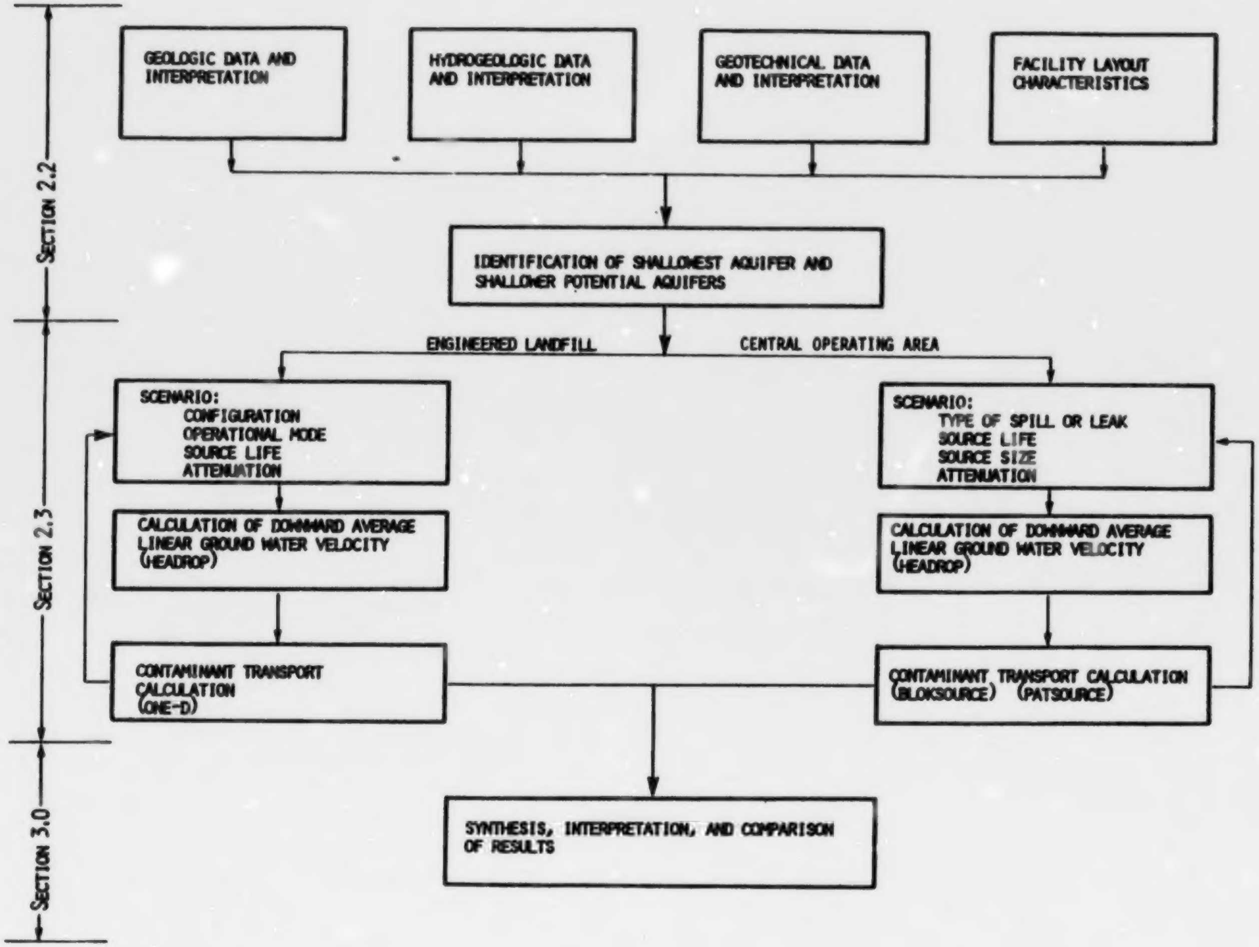
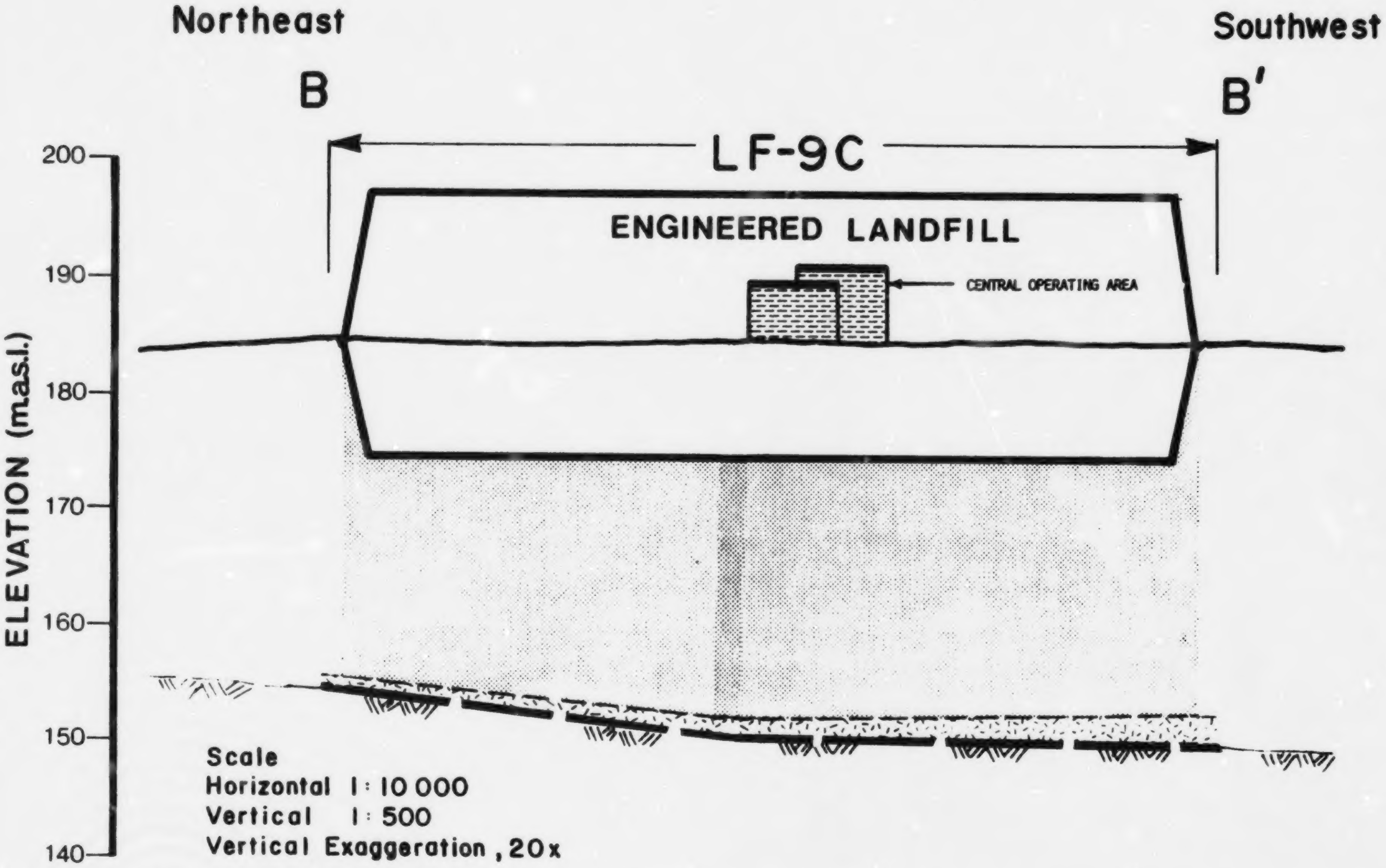

GEOLOGIC DATA AND INTERPRETATION
HYDROGEOLOGIC DATA AND INTERPRETATION
GEOTECHNICAL DATA AND INTERPRETATION
FACILITY LAYOUT CHARACTERISTICS
IDENTIFICATION OF SHALLOWEST AQUIFER AND SHALLOWER POTENTIAL AQUIFERS
ENGINEERED LANDFILL
CENTRAL OPERATING AREA
SCENARIO: CONFIGURATION OPERATIONAL MODE SOURCE LIFE ATTENUATION
CALCULATION OF DOWNWARD AVERAGE LINEAR GROUND WATER VELOCITY (HEADROP)
CONTAMINANT TRANSPORT CALCULATION (ONE-D)
SCENARIO: TYPE OF SPILL OR LEAK SOURCE LIFE SOURCE SIZE ATTENUATION
CALCULATION OF DOWNWARD AVERAGE LINEAR GROUND WATER VELOCITY (HEADROP)
CONTAMINANT TRANSPORT CALCULATION (BLOKSOURCE) (PATSOURCE)
SYNTHESIS, INTERPRETATION, AND COMPARISON OF RESULTS
SECTION 2.2
SECTION 2.3
SECTION 3.0

FIGURE A2 EXAMPLE OF SUPERIMPOSING FACILITIES ON CANDIDATE SITE LF-9C



INTERPRETIVE OVERBURDEN LEGEND GLAL BOREHOLE LOGS

■	CLAYEY SILT TO SILTY CLAY (Upper Galciolacustrine, Halton Till, Lower Galciolacustrine)
▨	SILT TILL (Lower Till)
▬	BEDROCK
----	Preliminary Interpretive Geologic Boundary
▬ ▬	Limit of Confining Layer

LEGEND

m.a.s.l. Metres Above Sea Level

NOTES: Elevations are approximate.

Base Section Source: Phase 4A Technical Appendix, LF-9C (Geologic Hydrogeologic and Geotechnical Considerations) generally retards ground water movement. The confining layer terminates at more permeable bedrock or at sand layers.

A surficial fractured zone occurs within 5 m. of ground surface. The water table exists within the fractured zone, generally close to surface. Potential for lateral ground water flow in the fractured zone exists, and there is also potential for significant discharge to local surface water systems as well. Research into fracture flow is presently underway at the University of Waterloo (John Cherry, personal communications) to further assess this potential pathway.

Downward gradients between the surface and the underlying bedrock result in downward ground water flow through the confining layer at all sites. Hence, permeable geologic deposits immediately underlying the confining layer (termed 'shallowest aquifer' in this appendix) are considered the first potential ground water pathway by which contaminants may move offsite if the potential for shallow, lateral ground water flow is discounted.

The shallowest aquifer at each site is indicated on Table A1. Identification of these aquifers is based on stratigraphic and water use data from the technical appendices. At Site LF-1E, several thin sand seams exist above the shallowest aquifer. These seams could behave as significant offsite contaminant pathways and have been identified for purposes of comparison as potential aquifers.

TABLE A1 SHALLOWEST AQUIFERS ASSUMED FOR GROUND WATER PATHWAY ANALYSIS

SITE	SHALLOWEST AQUIFER *
LF-3C	bedrock
LF-9C	bedrock
LF-1E	** bedrock
PI-27E	bedrock
LF-2N	uppermost sand layer
LF-4N	uppermost sand layer
PI-1N	uppermost sand layer
PI-13N	interbedded silt tills and sand unit

* Refer to cross sections (Figures 5 and 6) in each of the individual technical appendixes for details.

** Thin sand seams have been identified above the bedrock which may, assuming they have offsite continuity, be considered to be shallower potential aquifers at LF-1E.

A2.2.2 LAYOUT

Facility layouts have been developed for each candidate site by the engineering consultants, Monenco Limited. The layouts are presented in the report titled Site Selection Process, Phase 4A: Selection of a Preferred Site(s) - Engineering (Monenco Limited, 1985b). Unless otherwise noted, the positions and dimensions of the landfill and/or central operating area at each site conform to these facility layouts.

A2.2.3 INCINERATION AND PHYSICAL/CHEMICAL TREATMENT PLANTS

Preliminary engineering for the plant facilities are presented in the report titled Status Report, Facility Design and in the forementioned report (Monenco Limited, 1985a, 1985b). Excavations for tanks, pits, ponds, sewers, and pipes are currently expected to extend to a maximum depth of 8 m below ground surface. Other structures such as caisson or pile foundations, ground water monitors, and wells would probably extend below this depth. These other structures will be sealed into the soil and are not considered to be a pathway for offsite contaminant movement.

Monenco Limited (1985b) has established a list of possible contaminant sources for the central operating area. From this list, the following contaminant release scenarios were considered applicable for an assessment of contaminant transport:

(1) **spill residual scenario:**

This scenario assumes a contaminant residual would remain after the clean-up of a major spill or leak. Such an event could include a tanker truck overturning with spillage of its contents. Monenco (1985b) has estimated that a maximum volume of contaminated soil of about 4 m may be left as a residual that could not be readily accessed for remediation. Residual dimensions of 3 m x 3 m x 0.5 m (vertical dimension) were assumed for modelling purposes. This represents a liquid volume of about 1 m^3 to 2 m^3 in the soils. Since this waste residual could be present in the granular bedding below the paved areas or within the fractured zone of the underlying clays, it was assumed that a totally effective remediation could not be implemented during site operations.

(2) **subsurface leak scenario:**
Monenco Limited (1985b) has indicated that minor leaks could occur from several sources at the plant facilities, via cracks in building foundations and sumps, leaking joints in pipes, and leaking packing on valves, etc. Some of these leaks could potentially remain undetected until decommissioning, assumed to be about 20 years from start-up, for modelling purposes only. Realistically, multiple minor leaks could occur at different times throughout the facility life. This analysis considered a single subsurface leak located at 8 m below surface. The source is assumed to be small (0.1 m x 0.1 m) and the leak assumed to occur for the assumed 20 year operational life of the facility.

These examples were chosen for comparative purposes only.

A2.2.4 ENGINEERED LANDFILL

Three basic landfill designs are under consideration by OWMC:

(1) conventional
(2) above-ground
(3) shallow entombed

Figure 5 of the Status Report, Facility Design (Monenco Limited, 1985a) shows a schematic sketch of each configuration. Typical dimensions for each are provided in the Monenco Limited report. Initially, conventional landfill configuration (12 metre height above grade, 10 metre depth below grade) was compared at all sites.

In a subsequent analysis, the location and dimensions of the landfills were adjusted to accommodate site-specific considerations. These considerations, which are of a geotechnical and hydrogeologic nature, may represent potential constraints to landfill development and operation.

The following assumptions were applied to both the base case and site-adapted landfills:

- landfill is a uniform mass over the entire landfill area as opposed to individual cells or trenches with intervening fill (conservative approach);
- passive operational mode; no leachate collection from drainage systems; leachate in direct contact with natural soils.
- no liner system;
- water table at surface of landfill ('worst case' conditions);

- all outflows from the landfill are leachate; leachate produced throughout the landfill is of uniform composition;
- only post-construction (completed landfill) impacts are considered.

It should be stressed that these assumptions are not necessarily consistent with those of the engineering consultant, Monenco Limited but were chosen to facilitate modelling and hydrogeologic site comparison.

A2.2.5 CONTAMINANT CHARACTERISTICS

The composition and toxicity of potential contaminants can not be fully anticipated. At the physical/chemical treatment and incinerator facilities, contaminants could range from untreated waste to very dilute treated effluents. Leachate is identified as the contaminant source at the landfill.

The contaminants considered in this comparative analysis were conservatively assumed to be non-reactive with the in situ soils. A discussion of the potential influence of the attenuation process in the reduction of contaminant concentrations is provided in Section A2.4.1. In addition, dilution available in underlying aquifers was not considered.

Because of the uncertain chemical nature of the untreated wastes and treated waste residues, the analytical calculations in this assessment are based strictly on relative contaminant concentrations. Relative concentration (C/Co) is the ratio of the contaminant concentration (C) at some distance from the source and some time since introduction, to that at the source (Co).

Where a contaminant source persists indefinitely, relative concentrations at some distance away will increase from C/Co = 0 to nearly C/Co = 1.0. Breakthrough time for a continuous source was defined as the time required to reach C/Co = 0.1. This value is arbitrary and used only for comparison. On the other hand, where a contaminant source is of finite duration, relative concentrations at some distance away will generally increase from C/Co = 0 to some peak value and then decline again. In this case, the time at which the peak relative concentration occurs is identified as the breakthrough time.

A2.3 CALCULATIONS

A two-step procedure was used in the analysis of contaminant transport from the proposed landfill or central operating area through the confining layer to the shallowest aquifer at each candidate site. The first step involved the calculation of the downward average linear ground water velocities ($\bar{v}$) in all units between surface and the underlying bedrock. A computer model titled 'HEADROP', was used. This model is based principally on Darcy's Law of ground water flow as it applies to a layered system. HEADROP also calculates the leachate flux rate into the aquifer for each of the landfill configurations. Assumptions, theory, verification, examples, and more detailed descriptions of the HEADROP model are presented in Section A4.2.1.

For the second step, the calculated downward average linear ground water velocity from HEADROP was used to assess the rate of contaminant transport through the confining layer to the shallowest aquifer. Contaminants are transported through the soil by two primary mechanisms, advection and hydrodynamic dispersion. Advection is the bulk movement of contaminants by the flow of ground water, and is therefore directly related to the average linear ground water velocity (v). Hydrodynamic dispersion (D) includes those processes which tend to spread contaminants from the advective path. It has two components: (1) mechanical dispersion which is related to the dispersivity (α), and including the effect of the tortuous path of contaminants through the soil pores (termed 'tortuosity') and (2) diffusion which is described by the coefficient of molecular diffusion (D^*). These terms are related by the following equation:

$$D = \alpha \bar{v} + D^*$$

At very low ground water velocities, the mechanical dispersion terms become very small and contaminant transport is controlled by the diffusion process. Vertical one-dimensional contaminant transport calculations were used for the landfill calculations in this analysis because its proposed areal extent is large relative to the confining layer thickness at all of the candidate sites. A model called 'ONE-D', which is a selection of analytical solutions to the one-dimensional advection/dispersion equation, was used for this purpose. ONE-D calculates the breakthrough time through the confining layer to the aquifer at a specified relative concentration (C/Co of 0.1, assuming a continuous constant release rate from the source. This is representative of a landfill scenario where contaminants are leached at a constant rate from the waste residues for an indefinite period of time.

ONE-D was also used to calculate the peak relative concentration at the aquifer, and the lapsed time at which peak concentration would occur, for a finite duration, constant release rate source. This simulates a landfill scenario in which contaminants would be leached from the solidified mass at a constant rate for a fixed period of time. Because the actual leaching life of the solidified mass is not known, source lives of 100, 500 and 1000 years were used for purposes of comparison. Further details regarding the ONE-D model can be found in Section A4.3.2.

Two different models, "BLOKSOURCE" and "PATSOURCE", were used to evaluate contaminant transport from the physical/chemical treatment and incineration plant facilities to the shallowest aquifer. "BLOKSOURCE" was used for the spill residual scenario (see Section A2.2.3). This three-dimensional model simulates the transport of an instantaneous contaminant source of regular dimensions. As the contaminant plume moves downward it spreads outwards in all directions resulting in a reduction in contaminant concentration with distance from source. The peak relative concentration of contaminants at the aquifer, and the time at which this would be reached, were determined using the model. Further details regarding BLOKSOURCE are presented in Section A4.3.3.

"PATSOURCE", another three-dimensional, analytical model, was used to evaluate the subsurface leak scenario (see Section A2.2.3). PATSOURCE is similar to BLOKSOURCE except that the contaminant source is continuous rather than instantaneous. Again, peak relative concentration at the aquifer and the time at which this is reached were determined. Details regarding PATSOURCE can be found in Section A4.3.4.

The contaminant transport rate values reported for landfills are usually expressed as a range. For each landfill scenario analysed, two calculations are made which reflect the range in confining layer thickness below the site and consequently represent the slowest and fastest contaminant transport rates over the landfill area.

A single value is reported for contaminant concentration beneath the central operating area which represents conditions at approximately the centre of the proposed facility location.

A2.4 LIMITATIONS

Models use mathematical equations to simulate physical processes such as ground water flow and contaminant transport. The adequacy with which the mathematics of a particular model simulate the physical processes depends on careful application. However, it is generally recognized that geologic and hydrogeologic systems, which may be complex in reality, can only be modelled in an idealized fashion given practical and theoretical mathematical limits.

The major limitations involved in the models used in this assessment fall into two categories: modelling assumptions and input parameters. These will be considered in more detail in the following sections.

A2.4.1 LIMITATIONS RELATED TO MODELLING ASSUMPTIONS

A2.4.1.1 Vertical ground water flow

In calculating average linear ground water velocities using the HEADROP model, it was assumed that all flow is in a vertical direction between the landfill or central operating area and the bedrock aquifer underlying each candidate site. The overall hydraulic gradient between the water table (assumed to be at surface) and the piezometric level in the bedrock was assumed to be the dominant control on flow.

If substantial lateral gradients were to exist in any of the geologic units above the bedrock, then this assumption would be invalid. Lateral gradients of this type probably do not occur naturally at the candidate sites; however, they could be induced artificially for instance by pumping a well developed in a sand seam extending onto the site.

A2.4.1.2 Interacting flow systems

The calculated ground water velocities represent those beneath either the central operating area or the landfill. These velocities do not account for the hydrogeologic interaction that would occur if both the central operating area and landfill were together on a site, although this is a possibility (see Section A2.2.1). The degree of modelling sophistication required to assess interacting flow systems is not considered to be warranted for site comparison purposes.

A2.4.1.3 Attenuation

Most fine-grained soil deposits possess a capacity to chemically attenuate the migration of specific species. Thus the assumption that contaminants are non-reactive with the in situ ground water system would be very conservative for many organic and inorganic contaminant species.

A2.4.1.4 Dilute, dissolved contaminants

The contaminant transport models used in this assessment are based on the assumption of dilute contaminants migrating in solution. Landfill leachate, is assumed to contain only dilute, dissolved contaminants. The analysis presented for the central operating area scenarios, however, represents only the portion of the residual or leak that enters solution immediately. Immiscible contaminant species or those that can migrate considerable distances before entering solution are cases that have not been addressed here.

A2.4.1.5 Density and composition contrasts

The contaminant plume resulting from a potential source at either the landfill or plant facilities has been assumed in this analysis to have an equivalent density to the in situ ground water. Density contrasts could result in either increased or decreased vertical migration rates (Freeze and Cherry, 1979, pp. 396-397). Also, the hydraulic conductivity values assumed for all geologic materials is based on ground water flow. If a contaminant plume were to have physical/chemical properties significantly different from ground water, then suitable values of hydraulic conductivity would be required (Freeze and Cherry, 1979, pp. 26-30). The effect that certain chemical species could have on the physical characteristics of the in situ soils themselves (e.g. organics affecting soil structures) has not been considered in this analysis. While this is not considered to be a major factor at the landfill since primarily inorganic wastes will be disposed, chemical effects at the central operating area should be considered during Phase 4B.

A2.4.1.6 Additional modelling assumptions

Several additional assumptions are required that simplify the realistic contaminant transport processes:

- steady-state flow and transport
- constant release rate source for the landfill
- infinite or semi-infinite transport medium
- instantaneous release for the spill residual scenario.

A2.4.2 LIMITATIONS RELATED TO INPUT PARAMETERS

Section A4.1 presents the results of a limited parametric study directed at examining the sensitivity of the contaminant transport calculations to three confining layer properties: hydraulic conductivity, porosity, and hydraulic gradient (by varying the piezometric level in the bedrock). Two examples were used:

(1) Site LF-9C, conventional landfill design configuration, and

(2) Site PI-1N, spill residual scenario.

The results suggest that contaminant migration in these cases is more sensitive to changes in hydraulic conductivity than to porosity or gradient. It should also be recognized that hydraulic conductivity may vary over a larger range than the other parameters. Overall, changing all three of these parameters, which could possibly occur in the field due to natural geologic variability, can result in values of up to about an order of magnitude (or greater) difference (higher or lower) in contaminant transport times and peak concentrations relative to the values calculated in this analysis. This points to the need for more detailed assessments on the preferred site(s) to better define flow parameters.

Dispersivity (α) and the coefficient of molecular diffusion (D^*, including the effects of matrix tortuosity) are additional parameters required for the contaminant transport models. The following values were used in this study.

α = 0.1 m (longitudinal relative to flow direction)
α = 0.005 m (transverse relative to flow direction)
$D^* = 1\times10^{-10}$ m /s

The hydrodynamic dispersion coefficient (D), which describes long term spreading is given by:

$$D = \alpha \bar{v} + D^*$$

While these values are considered reasonable for comparative purposes, there is very little data available to confirm that these values are representative for fine-grained soils. At very low ground water velocities, the mechanical dispersion term (α) becomes very small and contaminant transport is controlled by the diffusion process.

The thicknesses of the various units are felt to be reasonably accurate, relative to the variations expected in the input parameters discussed above. However, the geologic interpretation is based on preliminary data only.

A2.4.3 SUMMARY

The limitations presented in this section imply that the numerical values in this appendix should not be interpreted as predictions of actual hydrogeologic performance under real-life conditions. However, because the site selection process is comparative, the limitations inherent in the models and input parameters are applied equally at each of the sites. Therefore the comparison of numerical values between candidate sites will be valid.

3.0 POTENTIAL IMPACTS

The potential movement impacts of contaminants in the ground water system at each candidate site were analysed using the techniques outlined in Section A2.3. The principal concern is that contaminants could migrate through the confining layer into the shallowest aquifer, and eventually contaminate water supplies developed in the aquifer. Therefore, this analysis focuses on contaminant transport to the shallowest aquifer at each of the candidate sites. The potential for contaminant movement laterally in the fractured zone is similar at all sites. As such, this assessment does not quantify fracture flow. This potential pathway should be addressed during Phase 4B.

A3.1 LANDFILL

The initial analysis considered the conventional landfill configuration (12 m height above grade, 10 m depth below grade) at candidate sites LF-3C, LF-9C, LF-1E, LF-2N, and LF-4N. Only breakthrough times to C/Co = 0.1 from a continuous, constant release rate source were compared in this initial effort. Table A2 summarizes the results.

In the subsequent analysis, each of the three alternative landfill configurations (conventional, above-ground, and shallow entombed) was considered. The dimensions of each landfill type were adjusted in accordance with hydrogeologic and/or geotechnical constraints. Site LF-2N was excluded from this subsequent analysis since it failed to pass the basic

TABLE A2 SUMMARY OF CONTAMINANT TRANSPORT MODELLING RESULTS - CONVENTIONAL LANDFILL

LANDFILL SITE		BREAKTHROUGH TIME* TO C/Co = 0.1 (Years)
LF-3C		350 - 1100
LF-9C		760 - 1100
LF-1E	a)	150 - 820
	b)	210
LF-2N		0** - 8
LF-4N		1 - 68

* for a continuous, constant release rate source

** excavation intersects aquifer, contaminants in direct contact

All breakthrough times are at the shallowest aquifer except LF-1E (b) which is at the overlying sand seam (potential aquifer).

acceptability screen (Section 3.3). The dimensions used are indicated by the heights and excavation depths shown on Table A3. Depth and/or height modifications were required for LF-3C, LF-9C, and LF-1E due to geotechnical constraints (see Techncial Appendices LF-3C, LF-9C, LF-1E). The base case dimensions (Monenco Limited, 1985a) were used for the above ground and shallow entombed alternatives with the following exclusions:

- the shallow entombed alternative is not feasible at LF-1E since excavation depths are restricted due to geotechnical constraints,
- the shallow entombed alternative is not included for LF-4N since excavations of the necessary depth would intersect the aquifer over large areas of the site, violating the basic acceptability requirements (i.e. hydrogeologic constraints).

The maximum Darcy flux from each of the landfills analysed in the modelling exercise are listed in Table A3. Leachate flux is a measure of specific discharge, or discharge of leachate per unit area of the landfill. This number can be interpreted as a relative indicator of the rate of contaminant loading on a per unit area basis to the aquifer at each site.

Breakthrough times to a relative concentration (C/Co) of 0.1 are included on Table A3 for comparative purposes. These represent transport from a continuous, constant release rate source.

In order to examine the influence of a finite duration,

TABLE A3 SUMMARY OF CONTAMINANT TRANSPORT MODELLING RESULTS - SITE-ADAPTED LANDFILLS

		LF-3C	LF-9C	LF-1E		LF-4N
				(a)	(b)	
CONVENTIONAL LANDFILL	MAXIMUM HEIGHT ABOVE GRADE (m)	4	4	1.5		12
	MAXIMUM EXCAVATION DEPTH BELOW GRADE (m)	10	10	5		10
	MAXIMUM LEACHATE FLUX FROM BASE OF LANDFILL (m/a)	0.0045-0.0078	0.0057-0.0069	0.0044-0.0095		0.036-0.31
	BREAKTHROUGH TIME TO C/Co = 0.1 (YEARS) *	600-1900	1200-1700	780-2500	1100	1-68
	PEAK RELATIVE CONCENTRATION BREAKTHROUGH TIME (YEARS) (100 YEAR SOURCE LIFE)	0.24-0.086 800-2400	0.16-0.11 1400-2100	0.30-0.082 960-3000	0.11 1500	1.0 3-130
	PEAK RELATIVE CONCENTRATION BREAKTHROUGH TIME (YEARS) (500 YEAR SOURCE LIFE)	0.48-0.41 1100-2600	0.69-0.52 1700-2300	0.95-0.39 1200-3200	0.50 1700	1.0 3-130
	PEAK RELATIVE CONCENTRATION BREAKTHROUGH TIME (YEARS) (1000 YEAR SOURCE LIFE)	1.0-0.72 1400-2900	0.95-0.84 2000-2600	1.0-0.69 1400-3500	0.81 2000	1.0 3-130
ABOVE-GROUND LANDFILL	MAXIMUM HEIGHT ABOVE GRADE (m)	12	12	12		12
	MAXIMUM EXCAVATION DEPTH BELOW GRADE (m)	0	0	0		0
	MAXIMUM LEACHATE FLUX FROM BASE OF LANDFILL (m/a)	0.0065-0.0099	0.0074-0.0082	0.0089-0.019		0.024-0.073
	BREAKTHROUGH TIME TO C/Co=0.1 (YEARS) *	700-1700	1200-1600	400-1300	500	9-150
	PEAK RELATIVE CONCENTRATION BREAKTHROUGH TIME (YEARS) (100 YEAR SOURCE LIFE)	0.27-0.13 900-2100	0.18-0.14 1500-1900	0.63-0.20 510-1600	0.28 680	1.0-0.96 40-240
	PEAK RELATIVE CONCENTRATION BREAKTHROUGH TIME (YEARS) (500 YEAR SOURCE LIFE)	0.91-0.57 1100-2300	0.74-0.63 1700-2200	1.0-0.80 650-1800	0.92 930	1.0 40-260
	PEAK RELATIVE CONCENTRATION BREAKTHROUGH TIME (YEARS) (1000 YEAR SOURCE LIFE)	1.0-0.88 1400-2600	0.97-0.93 2000-2500	1.0-0.99 650-2100	1.0 1100	1.0 40-260
SHALLOW ENTOMBED LANDFILL	MAXIMUM HEIGHT ABOVE GRADE (m)	0	0	NOT APPLICABLE - GEOTECHNICAL CONSTRAINTS		NOT APPLICABLE - HYDROGEOLOGIC CONSTRAINTS
	MAXIMUM EXCAVATION DEPTH BELOW GRADE (m)	15	15			
	MAXIMUM LEACHATE FLUX FROM BASE OF LANDFILL (m/a)	0.0029-0.0080	0.0057-0.0067			
	BREAKTHROUGH TIME TO C/Co=0.1 (YEARS) *	330-2000	810-1300			
	PEAK RELATIVE CONCENTRATION BREAKTHROUGH TIME (YEARS) (100 YEAR SOURCE LIFE)	0.33-0.056 480-2700	0.18-0.13 1100-1600			
	PEAK RELATIVE CONCENTRATION BREAKTHROUGH TIME (YEARS) (500 YEAR SOURCE LIFE)	0.96-0.27 740-2900	0.74-0.59 1300-1800			
	PEAK RELATIVE CONCENTRATION BREAKTHROUGH TIME (YEARS) (1000 YEAR SOURCE LIFE)	1.0-0.52 920-3200	0.97-0.89 1600-2100			

* for a continuous constant release rate source

All concentrations and breakthrough times are at the shallowest aquifer except LF-1E (b) which is at the overlying sand seam (potential aquifer) constant release rate source on contaminant transport, the peak relative concentrations and the time at which they occur (breakthrough time) are shown for source lives of 100, 500 and 1000 years.

The range shown for each value in Tables A2 and A3 results from stratigraphic variability. It is anticipated that the lower extreme of the breakthrough time ranges would be increased if the landfill position on each site were further adjusted to minimize areas of more rapid transport times. For example, this was done prior to this analysis at LF-1E to exclude the morainal feature called 'Walnut Hill'. Such adjustment would be of minimal benefit at sites such as LF-3C and LF-9C since the stratigraphic conditions are relatively uniform.

Table A4 summarizes the results of additional analyses on the conventional landfill design for LF-4N, to optimize contaminant breakthrough times. Column (a) shows the effect of limiting both the height and depth of the landfill to 5 m, while column (b) presents the results of a 5 m depth limitation in conjunction with restricting landfilling to portions of the site with confining layer thicknesses greater than 15 m.

A3.2 CENTRAL OPERATING AREA

Table A5 summarizes the results of the contaminant transport modelling for the central operating area. The peak relative concentration in the aquifer and the time at which this is reached (breakthrough time) for both the spill residual and subsurface leak scenarios are included (see Section 2.2.3,

TABLE A4 SUMMARY OF CONTAMINANT TRANSPORT MODELLING RESULTS - ADAPTED CONVENTIONAL LANDFILL AT LF-4N - MITIGATION FOR HYDROGEOLOGIC CONSTRAINTS

		(a)	(b)
ADAPTED CONVENTIONAL LANDFILL	MAXIMUM HEIGHT ABOVE GRADE (m) MAXIMUM EXCAVATION DEPTH BELOW GRADE (m)	5 5	12 5 *
	MAXIMUM LEACHATE FLUX FROM BASE OF LANDFILL (m/a)	0.010-0.040	0.024-0.042
	BREAKTHROUGH TIME TO C/Co = 0.1 (years)	34-360	57-150
	100 Year Source Life: PEAK RELATIVE CONCENTRATION BREAKTHROUGH TIME (years)	1.0-0.53 74-480	1.0-0.96 110-240
	500 Year Source Life: PEAK RELATIVE CONCENTRATION BREAKTHROUGH TIME (years)	1.0 74-660	1.0 110-260
	1000 Year Source Life: PEAK RELATIVE CONCENTRATION BREAKTHROUGH TIME (years)	1.0 74-660	1.0 110-260

* Includes restriction of landfill development to areas of total confining layer thickness of greater than 15 metres.

All concentrations and breakthrough times are at the shallowest aquifer.

TABLE A5 SUMMARY OF CONTAMINANT TRANSPORT MODELLING RESULTS – CENTRAL OPERATING AREA

	SPILL RESIDUAL SCENARIO *		SUBSURFACE LEAK SCENARIO *	
	Peak Relative Concentration	Breakthrough Time (years)	Peak Relative Concentration	Breakthrough Time (years)
LF-3C	0.0013	5200	3.7×10^{-9}	4300
LF-9C	0.0019	4000	7.5×10^{-9}	3400
LF-1E a)	0.0035	2600	2.2×10^{-9}	2200
b)	0.0096	1200	7.9×10^{-8}	830
PI-27E	0.0036	2600	1.7×10^{-8}	2000
PI-1N	0.16	29	1.1×10^{-4}	28
LF-2N	0.13	58	4.4×10^{-5}	47
LF-4N	0.0096	1200	7.8×10^{-4}	830
PI-13N	0.25	7	1.0	0**

* See Section 2.2 of this Appendix for a description of the scenario

** excavation intersects aquifer, contaminants in direct contact

All concentration and breakthrough times are at the shallowest aquifer except LF-1E (b) which is at the overlying sand seam (potential aquifer).

for a description of these scenarios).

One mitigative measure that could be considered is to limit all excavations to 5 m depth, rather than 8 m as proposed. Limiting excavations to less than 5 m depth may not be warranted since the fractured zone extends to an average depth of about 5 m and is not considered at this time to provide significant natural vertical containment.

A4.0 SUPPORTING INFORMATION

A4.1 INPUT PARAMETER SENSITIVITY STUDY

Tables A6 and A7 summarize the results of the sensitivity analysis performed to examine the impact of reasonable variations in input values for the following parameters:

- confining layer hydraulic conductivity (K)
- confining layer porosity (n)
- hydraulic gradient across confining layer (by varying piezometric level or "head" in the bedrock)

The sensitivity analysis was undertaken on a conventional landfill at Site LF-9C and a spill residual at the central operating area at Site PI-1N.

TABLE A6 SENSITIVITY STUDY FOR LF-9C, CONVENTIONAL LANDFILL * - NORTHEASTERN PART OF SITE

	BREAKTHROUGH TIME ($C/Co = 0.1$) TO AQUIFER, YEARS
INITIAL ASSUMPTIONS	760
K clayey silt = 3x10^{-10} m/s	
n clayey silt = 0.5	
Head In Bedrock = 176 m	
K clayey silt = 1x10^{-9} m/s	250
K clayey silt = 1x10^{-10} m/s	2100
n clayey silt = 0.4	630
n clayey silt = 0.6	900
Head In Bedrock = 174 m	700
Head In Bedrock = 178 m	840
"FASTEST" PARAMETER COMBINATION	180
K clayey silt = 1x10^{-9} m/s	
n clayey silt = 0.4	
Head In Bedrock = 174 m	
"SLOWEST" PARAMETER COMBINATION	2600
K clayey silt = 1x10^{-10}m/s	
n clayey silt = 0.6	
Head In Bedrock = 178 m	

* Dimensions: 12 m height above grade,
10 m depth below grade.

TABLE A7 SENSITIVITY STUDY FOR PI-1N, SPILL RESIDUAL SCENARIO

	PEAK RELATIVE CONCENTRATION IN AQUIFER AND TIME AT WHICH IT OCCURS
INITIAL ASSUMPTIONS K clayey silt till = 1×10^{-9} m/s n clayey silt till = 0.3 Head In Bedrock = 175 m	0.16 @ 29 years
K clayey silt till = 1×10^{-8} m/s	0.17 @ 6.7 years
K clayey silt till = 1×10^{-10} m/s	0.068 @ 240 years
n clayey silt till = 0.2	0.16 @ 25 years
n clayey silt till = 0.4	0.16 @ 33 years
Head In Bedrock = 173 m	0.16 @ 23 years
Head In Bedrock = 177 m	0.15 @ 38 years
"FASTEST" PARAMETER COMBINATION K clayey silt till = 1×10^{-8} m/s n clayey silt till = 0.2 Head In Bedrock = 173 m	0.17 @ 4.6 years
"SLOWEST" PARAMETER COMBINATION K clayey silt till = 1×10^{-10} m/s n clayey silt till = 0.4 Head In Bedrock = 177 m	0.047 @ 350 years

A4.2 MODEL DETAILS

The following Sections (A4.2.1 to A4.2.4, Appendix A) give details and example calculations for each of the computer models used in this analysis.

4.2.1 "HEADROP" MODEL

1. DESCRIPTION

AUTHOR: Gartner Lee Associates Limited

COMPUTER SYSTEM/LANGUAGE: Hewlett Packard HP9816/Basic

MODEL TYPE: Analytical, one-dimensional

ASSUMPTIONS:

- steady state, one-dimensional ground water flow through a fully saturated porous media profile layered perpendicular to the flow direction
- flow is governed by Darcy's Law
- each layer is homogeneous and isotropic with respect to material properties

INPUT PARAMETERS:

- for each layer: thickness, hydraulic conductivity, porosity
- total hydraulic potential (head) difference across entire profile

OUTPUT:

- head distribution throughout soil profile
- Darcy velocity (or discharge per unit area) through the profile
- average linear ground water velocity in each layer

2. THEORY

The following theory is summarized from Freeze and Cherry (1979, pp. 32-34).

Ground water discharge must be conserved through all layers of a profile under steady state conditions for an incompressible fluid (no internal sinks or sources). Therefore, employing Darcy's Law:

$$v = \frac{K_i \Delta h_i}{d_i} = \frac{K_e \Delta h}{d}$$

where: v = Darcy velocity (discharge per unit area, m/s)

K_i = hydraulic conductivity of any layer i (m/s)

Δh_i = head difference across any layer i (m)

d_i = thickness of any layer i the flow direction (m)

K_e = equivalent hydraulic conductivity for the entire profile (m/s)

Δh = head difference across the entire profile (m)

d = thickness of entire profile (m)

The solution for Ke is:

$$K_e = \frac{d}{\sum_{i=1}^{m} d_i/K_i}$$

where: m = total number of layers.

Thus v and Δh_i can be solved.

The averge linear ground water velocity in each layer is given by (Freeze and Cherry, 1979, p.71):

$$\bar{v} = \frac{v}{n_i}$$

where: n_1 = porosity of layer i

It can be proven that the "equivalent" porosity η_e for two or more layers is given by:

$$\eta_e = \frac{\eta_1 d_1 + \eta_2 d_2 + \ldots\ldots}{d_1 + d_2 + \ldots\ldots}$$

Therefore "equivalent" average linear ground water velocity is given by:

$$\bar{v}_e = \frac{v}{\eta_e}$$

3. VERIFICATION

The model was verified by comparison with hand-calculated examples using the equations outlined in the previous section.

4. EXAMPLE OUTPUT

The following is an example output from the HEADROP model.

EXAMPLE HEADROP OUTPUT

```
LF-3C: CONVENTIONAL LANDFILL - NORTHEAST SECTOR

TOTAL SPECIFIED HEAD DROP =     18        m
TOTAL CALCULATED HEAD DROP=     18        m

LAYER                       K       THICKNESS      HEAD DROP     POROSITY    VELOCIT[illegible] *
                          (m/s)        (m)            (m)                        (m/s)

WASTE                   5.00E-08     22.00          .11212        .3000     8.49E-1[illegible]
CLAYEY SILT             3.00E-10     21.00        17.83692 .      .5000     5.10E-1[illegible]
SILT TILL               1.00E-08      2.00          .05096        .3000     8.49E-10

* AVERAGE LINEAR GROUNDWATER VELOCITY

DARCY FLUX THROUGH ALL LAYERS IS: 2.55E-10 m/s
```

EQUIVALENT POROSITY:

$$n_e = (0.5*21 + 0.3*2) / (21 + 2) = 0.48$$

EQUIVALENT AVERAGE LINEAR GROUNDWATER VELOCITY:

$$\bar{v}_e = 2.55E-10 / 0.48 = 5.28E-10$$

A4.2.2 "ONE-D" MODEL

1. DESCRIPTION

AUTHOR: Gartner Lee Associates Limited

COMPUTER SYSTEM/ LANGUAGE Hewlett Packard HP9816/Basic

MODEL TYPE: analytical, one-dimensional

ASSUMPTIONS:

- contaminant transport is governed by the advection/dispersion equation
- profile is fully saturated
- porous medium is homogeneous and isotropic
- transport medium is semi-infinite
- contaminant transport is one-dimensional; lateral transport is negligible
- contaminant release rate from the source is constant for the active life of the source

INPUT PARAMETERS:

- choice of two source types:
  (1) continuous source, or
  (2) finite duration source
- source life
- choice of attenuation processes:
  (1) no attenuation
  (2) sorption and/or first order decay
    - distribution coefficient for chemical species, and porosity and bulk density of porous medium for sorption calculation
    - chemical species halflife for first order decay calculation

INPUT PARAMETERS (cont'd)

- average linear ground water velocity
- dispersion coefficient, or coefficient of molecular diffusion and dispersivity
- time and distance for each calculation

OUTPUT

- profiles of relative concentration versus: (1) time at a specific distance, or (2) distance at a specific time
- data table printout and/or data plots

2. THEORY

The governing differential equation for one-dimensional contaminant transport in a saturated, homogeneous, isotropic porous medium is (modified from Cleary and Ungs, 1978):

$$\frac{\partial C}{\partial t} + \bar{v}\frac{\partial C}{\partial x} = D\frac{\partial^2 C}{\partial x^2} - \lambda C$$

where: $\bar{v}$ = average linear ground water velocity (m/s)

x = distance from source (m)

D = dispersion coefficient (m^2/s)

= $\alpha\bar{v} + D^*$ (Freeze and Cherry, 1979, p.389-390)

α = dispersivity (m)

D^* = coefficient of molecular diffusion (m^2/s)

λ = first order decay constant (s^{-1})

= $\frac{\ln(2)}{t_{\frac{1}{2}}}$

$t_{\frac{1}{2}}$ = contaminant species halflife for the particular first order decay process (s)

C = contaminant concentration (example, mg/L)

Cleary and Ungs developed the following solution to this equation for a continuous constant release rate source:

$$\begin{aligned}\frac{C}{Co}(x,t) = \frac{1}{2}\Bigg\{ & \exp\left[\frac{x\bar{v}}{2D} - \frac{x}{\sqrt{D}}\sqrt{\frac{\bar{v}^2}{4D}+\lambda}\right] \\ & \bullet \operatorname{erfc}\left[\frac{x}{2\sqrt{Dt}} - \sqrt{\left(\frac{\bar{v}^2}{4D}+\lambda\right)t}\right] + \exp\left[\frac{x\bar{v}}{2D} + \frac{x}{\sqrt{D}}\sqrt{\frac{\bar{v}^2}{4D}+\lambda}\right] \\ & \bullet \operatorname{erfc}\left[\frac{x}{2\sqrt{Dt}} + \sqrt{\left(\frac{\bar{v}^2}{4D}+\lambda\right)t}\right]\Bigg\}\end{aligned}$$

where: Co = source contaminant concentration (example, mg/L)

$\frac{C}{Co}(x,t)$ = relative concentration

exp = exponential function

erfc = complementary error function

Sorption can be included in this solution by dividing $\bar{v}$, D and λ by the retardation factor (r) defined as (Freeze and Cherry, 1979, p. 404):

$$r = 1 + \frac{\rho_b}{n} \bullet Kd$$

where: ρ_b = porous medium bulk density (g/cm³)
n = porous medium porosity
Kd = distribution coefficient for the chemical species (mL/g)

Dividing λ by r assumes that contaminant sorbed on the solid phase is restricted from further first order decay.

A finite duration constant release rate source can be simulated by employing Duhamel's Theory (Hildebrand, 1962, p. 451) which involves superposition of solutions in time:

$$\frac{C'}{Co}(x,t) = \frac{C}{Co}(x,t) - \frac{C}{Co}(x,t-t_o)$$

where: $\frac{C'}{Co}$ = relative concentration for a fixed duration, constant release rate source

$\frac{C}{Co}$ = relative concentration for a continuous constant release rate source

t_o = source life (s)

3. VERIFICATION

Cleary and Ungs (1978) give an example using this equation including first order decay. This example was matched using ONE-D for a continuous constant release rate source.

With no attenuation processes and a continuous, constant release rate source, this solution degenerates to the solution derived by Ogata and Banks (1961). Their solution is available as a computer program at University of Waterloo. ONE-D was verified with the University of Waterloo model.

The sorption and finite duration source routines were verified by hand calculation and multiple runs with parts of the program previously verified.

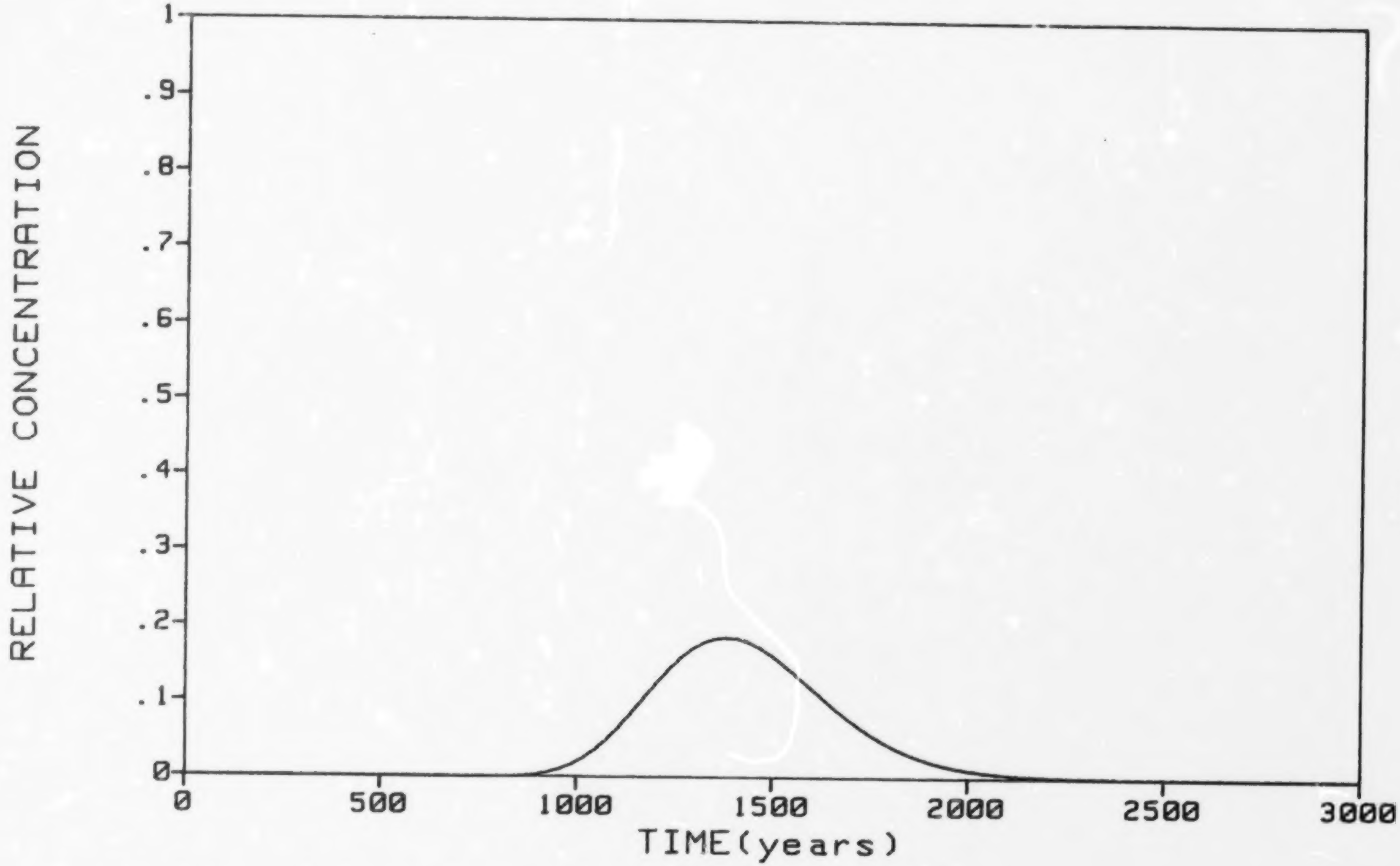
4. EXAMPLE OUTPUT

The following pages show example output from the ONE-D model.

EXAMPLE ONE-D OUTPUT

```
ONE-DIMENSIONAL CONTAMINANT TRANSPORT SOLUTION

LF-3C: CONVENTIONAL LANDFILL - NORTHEAST SECTOR

SUMMARY OF INPUT PARAMETERS:
----------------------------
     A finite duration constant release rate source is specified
     Time that the source is active (years)          100.00


     Average linear groundwater velocity (m/s)     +5.28E-10
     Dispersivity (m)                                    .10
     Molecular diffusion coefficient (m*m/s)       1.00E-10
     CALCULATED Dispersion coefficient (m*m/s)     1.53E-10
     Distance for breakthrough calculation (m)         23.00
     Start time for calculations (years)                   0
     End time for calculations (years)                  3000


     CONCENTRATION VS. TIME

     TIME     C/Co        TIME     C/Co        TIME     C/Co        TIME     C/Co
    (years)              (years)              (years)              (years)

      0.0   0.00000       30.0   0.00000       60.0   0.00000       90.0   0.00000
    120.0   0.00000      150.0   0.00000      180.0   0.00000      210.0   0.00000
    240.0   0.00000      270.0   0.00000      300.0   0.00000      330.0   0.00000
    360.0   0.00000      390.0   0.00000      420.0   0.00000      450.0   0.00000
    480.0   0.00000      510.0   0.00000      540.0   0.00000      570.0   0.00000
    600.0   0.00000      630.0   0.00000      660.0   0.00000      690.0    .00001
    720.0    .00002      750.0    .00006      780.0    .00017      810.0    .00041
    840.0    .00093      870.0    .00193      900.0    .00370      930.0    .00661
    960.0    .01110      990.0    .01758     1020.0    .02639     1050.0    .03771
   1080.0    .05153     1110.0    .06754     1140.0    .08520     1170.0    .10375
   1200.0    .12227     1230.0    .13978     1260.0    .15536     1290.0    .16821
   1320.0    .17772     1350.0    .18354     1380.0    .18555     1410.0    .18389
   1440.0    .17887     1470.0    .17096     1500.0    .16075     1530.0    .14883
   1560.0    .13580     1590.0    .12223     1620.0    .10860     1650.0    .09533
   1680.0    .08271     1710.0    .07099     1740.0    .06031     1770.0    .05073
   1800.0    .04228     1830.0    .03493     1860.0    .02862     1890.0    .02326
   1920.0    .01876     1950.0    .01503     1980.0    .01195     2010.0    .00944
   2040.0    .00742     2070.0    .00579     2100.0    .00449     2130.0    .00347
   2160.0    .00266     2190.0    .00203     2220.0    .00155     2250.0    .00117
   2280.0    .00088     2310.0    .00066     2340.0    .00050     2370.0    .00037
   2400.0    .00027     2430.0    .00020     2460.0    .00015     2490.0    .00011
   2520.0    .00008     2550.0    .00006     2580.0    .00004     2610.0    .00003
   2640.0    .00002     2670.0    .00002     2700.0    .00001     2730.0    .00001
   2760.0    .00001     2790.0   0.00000     2820.0   0.00000     2850.0   0.00000
   2880.0   0.00000     2910.0   0.00000     2940.0   0.00000     2970.0   0.00000
```

FIGURE A3 EXAMPLE OUTPUT FOR A ONE-DIMENSIONAL CONTAMINANT TRANSPORT SOLUTION



LF-3C: CONVENTIONAL LANDFILL - NORTHEAST SECTOR

A4.2.3 "BLOKSOURCE" MODEL

1. DESCRIPTION

AUTHOR: Gartner Lee Associates Limited

COMPUTER SYSTEM/ LANGUAGE: Hewlett Packard HP9816/Basic

MODEL TYPE: analytical, three-dimensional

ASSUMPTIONS:

- steady state ground water flow in a saturated, infinite porous medium
- contaminant transport is governed by the advection/dispersion equation
- porous medium is isotropic and homogeneous in each coordinate direction
- contaminant is released as an instantaneous slug with regular block-shaped dimensions

INPUT PARAMETERS:

- choice of attenuation processes:
  (1) no attenuation
  (2) sorption and/or first order decay
    - distribution coefficient for chemical species, and porosity and bulk density of porous medium for sorption calculation
    - chemical species halflife for first order decay calculation
- initial dimensions of the source
- average linear ground water velocity
- coefficient of molecular diffusion, and dispersivity in each of the coordinate directions

OUTPUT:

- profiles of relative concentration versus: (1) time at a specific distance, or (2) distance at a specific time
- data table printout and/or data plots

2. THEORY

The governing differential equation for three-dimensional contaminant transport in a saturated, homogeneous, isotropic porous medium is (modified from Cleary and Ungs, 1978).

$$\frac{\partial C}{\partial t} + \bar{v}_x \frac{\partial C}{\partial x} + \bar{v}_y \frac{\partial C}{\partial y} + \bar{v}_z \frac{\partial C}{\partial z} = D_x \frac{\partial^2 C}{\partial x^2} + D_y \frac{\partial^2 C}{\partial y^2} + D_z \frac{\partial^2 C}{\partial z^2} - \lambda C$$

where:

$\bar{v}_x, \bar{v}_y, \bar{v}_z$ = average linear ground water velocity in each coordinate direction (m/s)

x, y, z = distance in each coordinate direction (m)

D_x, D_y, D_z = dispersion coefficient in each coordinate direction (m^2/s)

D = $\alpha\bar{v}+D^*$

α = dispersivity in each coordinate direction (m)

D^* = coefficient of molecular diffusion (m^2/s)

λ = first order decay constant (s^{-1})

= $\frac{\ln(2)}{t_{\frac{1}{2}}}$

$t_{\frac{1}{2}}$ = contaminant species halflife for the particular first order decay process (s)

C = contaminant concentration (example, mg/L)

Carslaw and Jaeger (1959) developed the following solution for an instantaneous rectangular parallelopiped (block) source:

$$\frac{C}{Co}(x,y,z,t)=\frac{\exp(-\lambda t)}{8}\left[\operatorname{erf}\left(\frac{x-\bar{v}_x t+Xo/2}{2\sqrt{D_x t}}\right)-\operatorname{erf}\left(\frac{x-\bar{v}_x t-Xo/2}{2\sqrt{D_x t}}\right)\right]$$

$$\bullet\left[\operatorname{erf}\left(\frac{y+Yo/2}{2\sqrt{D_y t}}\right)-\operatorname{erf}\left(\frac{y-Yo/2}{2\sqrt{D_y t}}\right)\right]$$

$$\bullet\left[\operatorname{erf}\left(\frac{z+Zo/2}{2\sqrt{D_z t}}\right)-\operatorname{erf}\left(\frac{z-Zo/2}{2\sqrt{D_z t}}\right)\right]$$

where:

X_o, Y_o, Z_o = source dimensions in each coordinate direction (m)

Co = source contaminant concentration (example mg/L)

$\frac{C}{Co}(x,y,z,t)$ = relative concentration

exp = exponential function

erf = error function

Sorption can be included in this solution by dividing $\bar{v}$, Dx, Dy, Dz and λ by the retardation factor (r) defined as (Freeze and Cherry, 1979, p.404):

$$r = 1 + \frac{\rho_b}{n} K_d$$

where: ρ_b = porous medium bulk density (g/cm³)

n = porous medium porosity

K_d = distribution coefficient for the chemical species (mL/g)

Dividing λ by r assumes that contaminant sorbed on the solid phase is restricted from further first order decay.

3. VERIFICATION

Sudicky et al. (1983) used this solution to compare to field observations. Attenuation was not considered. BLOKSOURCE was verified against example outputs from this study.

The attenuation routines were verified by hand calculation and multiple runs with parts of the program previously verified.

4. EXAMPLE OUTPUT

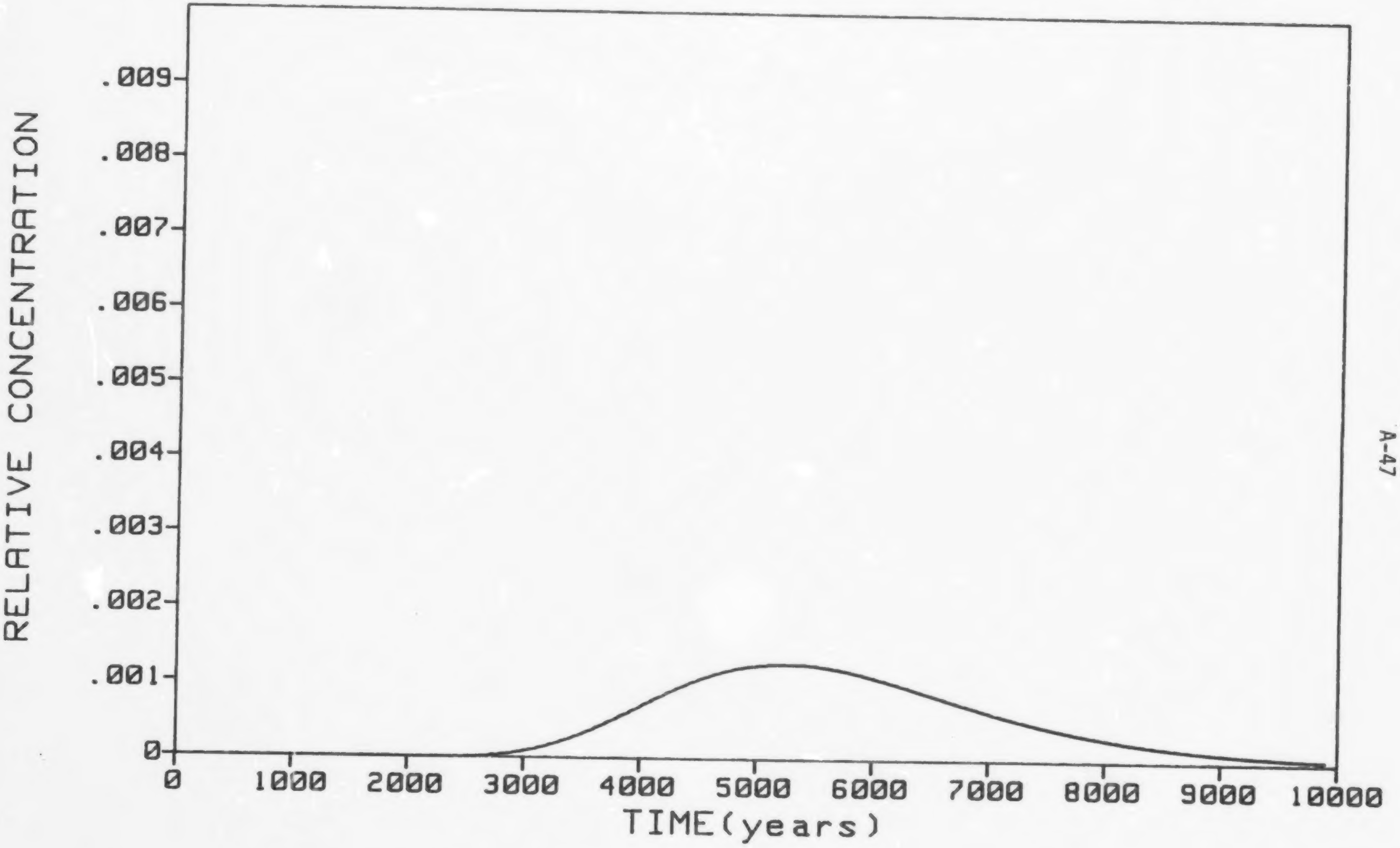
The following pages show example output from the BLOKSOURCE model.

EXAMPLE BLOKSOURCE OUTPUT

```
SOLUTION FOR AN INSTANTANEOUS BLOCK CONTAMINANT SOURCE

LF-3C: SPILL RESIDUAL SCENARIO

THE X,Y,Z DIMENSIONS OF THE SOURCE :  .5m, 3.0m, 3.0m
AVERAGE LINEAR GROUND WATER VELOCITY :1.44E-10 m/s
COEFFICIENT OF MOLECULAR DIFFUSION :1.00E-10 m^2/s
DISPERSIVITY IN X-DIRECTION (PARALLEL TO GROUND WATER FLOW) :  .1000 m
DISPERSIVITY IN Y-DIRECTION :  .0050 m
DISPERSIVITY IN Z-DIRECTION :  .0050 m
DISTANCE FOR TRANSPORT CALCULATIONS, THE X-COORDINATE:26.00 m
DISTANCE FROM THE CENTRE OF THE PLUME,THE Y,Z COORDINATES : 0.00m, 0.00m
START TIME AND END TIME FOR CALCULATIONS (years)   0.00 10000.00



TIME (years)     RELATIVE CONCENTRATION
------------     ----------------------
       0.000           0.00000000
     100.000           0.00000000
     200.000           0.00000000
     300.000           0.00000000
     400.000           0.00000000
     500.000           0.00000000
     600.000           0.00000000
     700.000           0.00000000
     800.000           0.00000000
     900.000           0.00000000
    1000.000           0.00000000
    1100.000           0.00000000
    1200.000           0.00000000
    1300.000           0.00000000
    1400.000           0.00000000
    1500.000           0.00000000
    1600.000           0.00000000
    1700.000            .00000001
    1800.000            .00000003
    1900.000            .00000010
    2000.000            .00000028
    2100.000            .00000069
    2200.000            .00000153
    2300.000            .00000314
    2400.000            .00000597
    2500.000            .00001064
    2600.000            .00001789
    2700.000            .00002858
    2800.000            .00004363
    2900.000            .00006395
    3000.000            .00009034
    3100.000            .00012347
    3200.000            .00016378
    3300.000            .00021141
    3400.000            .00026624
    3500.000            .00032779
    3600.000            .00039532
    3700.000            .00046781
    3800.000            .00054402
```

3900.000	.00062257
4000.000	.00070196
4100.000	.00078068
4200.000	.00085725
4300.000	.00093027
4400.000	.00099847
4500.000	.00106074
4600.000	.00111618
4700.000	.00116406
4800.000	.00120388
4900.000	.00123534
5000.000	.00125834
5100.000	.00127294
5200.000	.00127936
5300.000	.00127796
5400.000	.00126922
5500.000	.00125369
5600.000	.00123199
5700.000	.00120478
5800.000	.00117276
5900.000	.00113661
6000.000	.00109703
6100.000	.00105467
6200.000	.00101017
6300.000	.00096411
6400.000	.00091706
6500.000	.00086949
6600.000	.00082188
6700.000	.00077460
6800.000	.00072801
6900.000	.00068240
7000.000	.00063803
7100.000	.00059509
7200.000	.00055375
7300.000	.00051413
7400.000	.00047634
7500.000	.00044042
7600.000	.00040641
7700.000	.00037432
7800.000	.00034415
7900.000	.00031586
8000.000	.00028941
8100.000	.00026476
8200.000	.00024183
8300.000	.00022056
8400.000	.00020087
8500.000	.00018269
8600.000	.00016594
8700.000	.00015053
8800.000	.00013639
8900.000	.00012342
9000.000	.00011157
9100.000	.00010074
9200.000	.00009086
9300.000	.00008187
9400.000	.00007369
9500.000	.00006627
9600.000	.00005954
9700.000	.00005344
9800.000	.00004793
9900.000	.00004295

FIGURE A4. EXAMPLE OUTPUT FOR AN INSTANTANEOUS BLOCK CONTAMINANT SOURCE SOLUTION



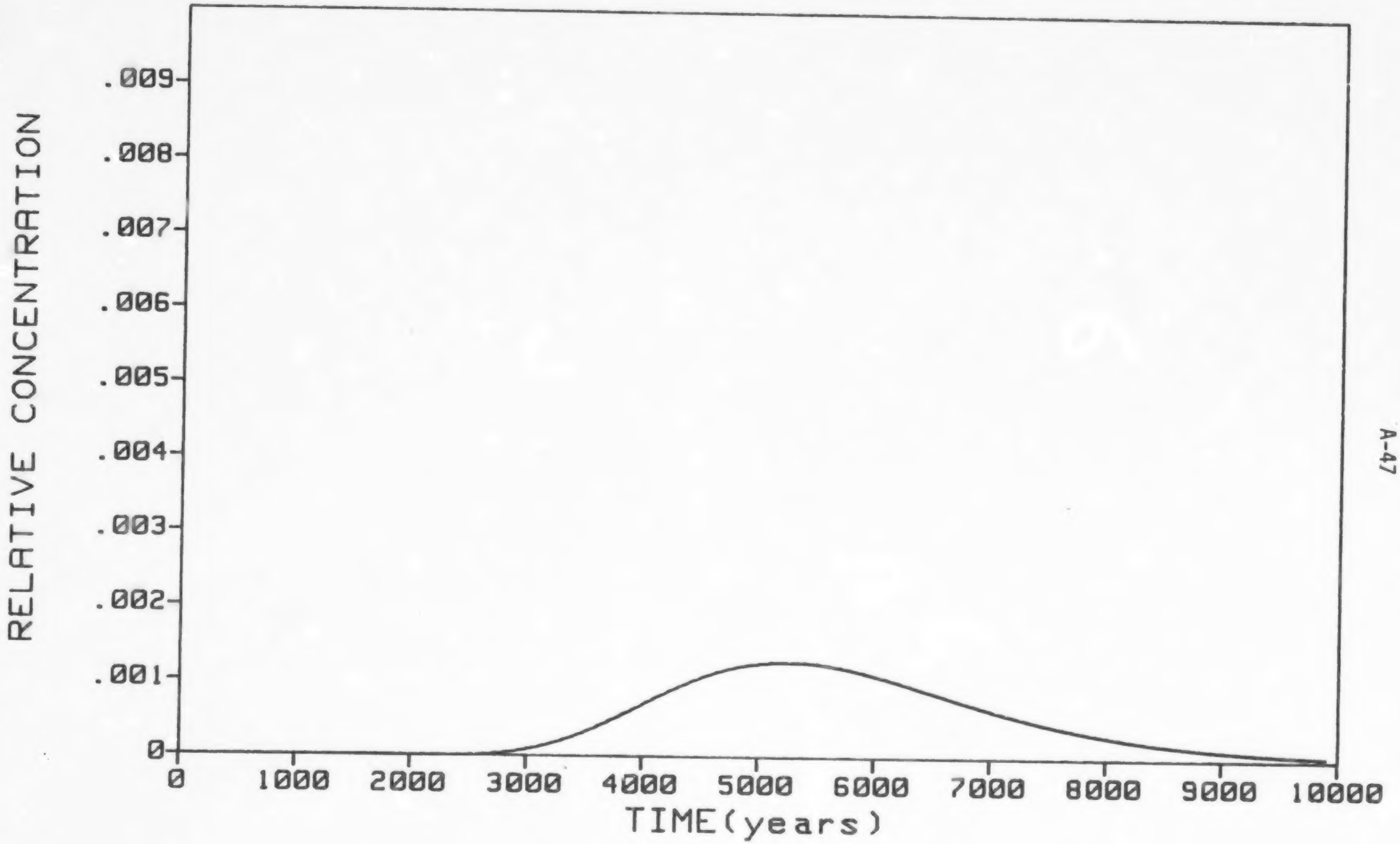
LF-3C: SPILL RESIDUAL SCENARIO

A4.2.4 "PATSOURCE" MODEL:

1. DESCRIPTION

AUTHOR:	Gartner Lee Associates Limited
COMPUTER SYSTEM/ LANGUAGE	Hewlett Packard HP9816/Basic
MODEL TYPE:	analytical with numerical integration, three-dimensional
ASSUMPTIONS:	● steady state ground water flow through a fully saturated porous medium which is homogeneous and isotropic with respect to material properties ● contaminant transport governed by the advection/dispersion equation ● semi-infinite transport medium ● constant contaminant release rate during the active source life
INPUT PARAMETERS:	● source type: (1) continuous release source (2) finite duration source with appropriate source life ● source dimensions ● choice of attenuation processes: (1) no attenuation (2) ● distribution coefficient for chemical species, and porosity and bulk density of porous medium for sorption calculation ● chemical species halflife for first order decay calculation ● average linear ground water velocity ● dispersion coefficient, or coefficient of molecular diffusion and dispersivity, in each coordinate direction

FIGURE A4. EXAMPLE OUTPUT FOR AN INSTANTANEOUS BLOCK CONTAMINANT SOURCE SOLUTION



LF-3C: SPILL RESIDUAL SCENARIO

A4.2.4 "PATSOURCE" MODEL:

1. DESCRIPTION

AUTHOR:	Gartner Lee Associates Limited
COMPUTER SYSTEM/ LANGUAGE	Hewlett Packard HP9816/Basic
MODEL TYPE:	analytical with numerical integration, three-dimensional
ASSUMPTIONS:	• steady state ground water flow through a fully saturated porous medium which is homogeneous and isotropic with respect to material properties • contaminant transport governed by the advection/dispersion equation • semi-infinite transport medium • constant contaminant release rate during the active source life
INPUT PARAMETERS:	• source type: (1) continuous release source (2) finite duration source with appropriate source life • source dimensions • choice of attenuation processes: (1) no attenuation (2) • distribution coefficient for chemical species, and porosity and bulk density of porous medium for sorption calculation • chemical species halflife for first order decay calculation • average linear ground water velocity • dispersion coefficient, or coefficient of molecular diffusion and dispersivity, in each coordinate direction

- time and location for calculation
- number of numerical integration points required

OUTPUT:

- profiles of relative concentration versus:
  (1) time at a specified distance, or,
  (2) distance at a specified time
- data table printout and/or data plots

2. THEORY

The following equation describes three-dimensional contaminant transport from an area source in a saturated, isotropic, homogeneous porous medium (modified from Carslaw and Jaeger, 1959, p. 371):

$$\frac{C}{Co}(x,y,z,t) = \frac{x}{8\Pi^{3/2}\left(D_xD_yD_z\right)^{1/2}} \int_0^t \int_{-\frac{z_o}{2}}^{\frac{z_o}{2}} \int_{-\frac{y_o}{2}}^{\frac{y_o}{2}} \frac{1}{\tau^{5/2}} \left[\exp \frac{-(x-\bar{v}t)^2}{4Dx} - \lambda\tau\right]$$

$$\bullet \exp\left[\frac{-(y-y')^2}{4D_y\tau}\right] \bullet \exp\left[\frac{-(z-z')^2}{4D_z\tau}\right] \quad D_y{}'D_z{}'D_r$$

where:

Co = source contaminant concentration (example, mg/L)

$\frac{C}{Co}$ (x,y,z,t) = relative concentration

x,y,z = distance in each coordinate direction (m)

t = time since introduction of source (s)

D_x, D_y, D_z = dispersion coefficient in each coordinate direction (m^2/s)

$$D = \alpha\bar{V} + D^*$$

α = dispersivity (m)

$\bar{v}$ = average linear ground water velocity (m/s)

D^* = coefficient of molecular diffusion (m^2/s)

y_o, z_o = source dimensions (m)

τ = time (s)

exp = exponential function

λ = first order decay constant (s^{-1})

y', z' = coordinates at time τ (m)

Integrating and simplifying yields the following solution:

$$\frac{C}{Co}(x,y,z,t) = \frac{x}{8\pi^{1/2} D_x^{1/2}} \int_0^t \frac{1}{\tau^{3/2}} \exp\left[\frac{-(x-\bar{v}\tau)^2}{4D_x\tau} - \lambda\tau\right]$$

$$\bullet \left[\operatorname{erf}\left\{\frac{y+y_o/2}{2(D_y\tau)^{1/2}}\right\} - \operatorname{erf}\left\{\frac{y-y_o/2}{2(D_y\tau)^{1/2}\tau}\right\}\right]$$

$$\bullet \operatorname{erf}\left[\left\{\frac{z+z_o/2}{2(D_z\tau)^{1/2}}\right\} - \operatorname{erf}\left\{\frac{z-z_o/2}{2(D_z\tau)^{1/2}}\right\}\right] \quad d\tau$$

where: erf = error function.

The integral in this equation is solved numerically using a Gauss Quadrature technique.

Sorption can be included in this solution by dividing v, Dx, Dy, Dz and λ by the retardation factor (r) defined as (Freeze and Cherry, 1979, p. 404):

$$r = 1 + \frac{\rho_b}{n} K_d$$

where: ρb = porous medium bulk density (g/cm^3)

n = porous medium porosity

K_d = distribution coefficient for the chemical species (mL/g)

Dividing λ by r assumes that contaminant sorbed on the solid phase is restricted from further first order decay.

3. VERIFICATION

The theory for PATSOURCE was independently checked by E.A. Sudicky of the Groundwater Research Institute, University of Waterloo. The model was developed using standard subroutines previously verified. Runs were made using a very large source and compared to corresponding runs using a one-dimensional solution which had been previously verified.

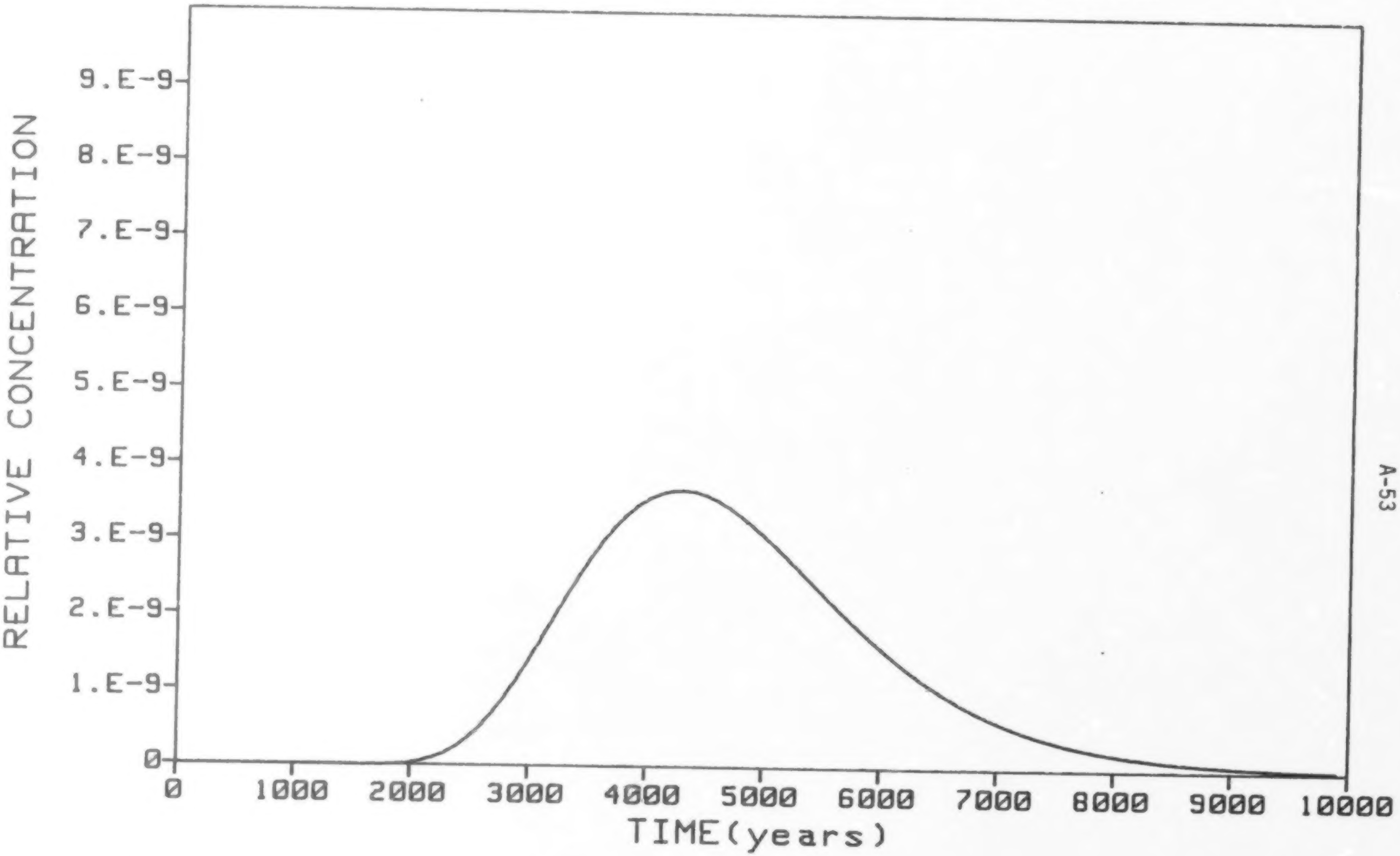
4. EXAMPLE OUTPUT

The following pages show example output from the PATSOURCE model.

EXAMPLE PATSOURCE OUTPUT

```
THREE-DIMENSIONAL CONTAMINANT TRANSPORT SOLUTION

LF-3C: SUBSURFACE LEAK SCENARIO

SUMMARY OF INPUT PARAMETERS:
----------------------------
     A finite duration constant release rate source is specified
Time that the source is active (years)                  20.00
Source dimensions in the X,Y directions(m)             .01,  .01


Average linear groundwater velocity (m/s)            +1.44E-10
Dispersivity: X,Y,Z directions (m)                     .10000,  .00500,  .00500
Molecular diffusion coefficient (m*m/s)              1.00E-10
Dispersion coefficients: X,Y,Z directions(m*m/s)     1.14E-10,1.01E-10,1.01E-10
Distance from plume axis: Y,Z cordinates(m)            0.00,  0.00
Distance along plume axis: X coordinate (m)              23.00
Start time for calculations (years)                          0
End time for calculations (years)                       10000
Number of steps in calculation                       100
Number of Gauss integration points                   20


    CONCENTRATION VS. TIME

     TIME      C/Co          TIME      C/Co          TIME      C/Co          TIME      C/Co
   (years)                 (years)                 (years)                 (years)

      0.0   0.000E+00       100.0   0.000E+00       200.0   1.909E-80       300.0   4.636E-5[illegible]
    400.0   6.405E-41       500.0   4.363E-33       600.0   6.460E-28       700.0   2.865E-24
    800.0   1.424E-21       900.0   1.653E-19      1000.0   6.968E-18      1100.0   1.410E-16
   1200.0   1.651E-15      1300.0   1.271E-14      1400.0   7.048E-14      1500.0   3.012E-13
   1600.0   1.042E-12      1700.0   3.033E-12      1800.0   7.647E-12      1900.0   1.710E-11
   2000.0   3.452E-11      2100.0   6.389E-11      2200.0   1.098E-10      2300.0   1.767E-10
   2400.0   2.690E-10      2500.0   3.896E-10      2600.0   5.403E-10      2700.0   7.210E-10
   2800.0   9.297E-10      2900.0   1.163E-09      3000.0   1.415E-09      3100.0   1.680E-09
   3200.0   1.950E-09      3300.0   2.219E-09      3400.0   2.480E-09      3500.0   2.725E-09
   3600.0   2.949E-09      3700.0   3.147E-09      3800.0   3.317E-09      3900.0   3.454E-09
   4000.0   3.559E-09      4100.0   3.630E-09      4200.0   3.669E-09      4300.0   3.676E-09
   4400.0   3.655E-09      4500.0   3.607E-09      4600.0   3.535E-09      4700.0   3.443E-09
   4800.0   3.333E-09      4900.0   3.208E-09      5000.0   3.072E-09      5100.0   2.928E-09
   5200.0   2.777E-09      5300.0   2.623E-09      5400.0   2.467E-09      5500.0   2.312E-09
   5600.0   2.159E-09      5700.0   2.009E-09      5800.0   1.864E-09      5900.0   1.723E-09
   6000.0   1.589E-09      6100.0   1.461E-09      6200.0   1.340E-09      6300.0   1.226E-09
   6400.0   1.120E-09      6500.0   1.020E-09      6600.0   9.271E-10      6700.0   8.410E-10
   6800.0   7.615E-10      6900.0   6.883E-10      7000.0   6.210E-10      7100.0   5.594E-10
   7200.0   5.032E-10      7300.0   4.519E-10      7400.0   4.053E-10      7500.0   3.629E-10
   7600.0   3.246E-10      7700.0   2.900E-10      7800.0   2.587E-10      7900.0   2.306E-10
   8000.0   2.053E-10      8100.0   1.826E-10      8200.0   1.622E-10      8300.0   1.440E-10
   8400.0   1.277E-10      8500.0   1.131E-10      8600.0   1.001E-10      8700.0   8.856E-11
   8800.0   7.827E-11      8900.0   6.912E-11      9000.0   6.100E-11      9100.0   5.379E-11
   9200.0   4.741E-11      9300.0   4.175E-11      9400.0   3.675E-11      9500.0   3.233E-[illegible]
   9600.0   2.842E-11      9700.0   2.497E-11      9800.0   2.193E-11      9900.0   1.925E-[illegible]
```

FIGURE A5   EXAMPLE FOR A THREE-DIMENSIONAL CONTAMINANT TRANSPORT SOLUTION



LF-3C: SUBSURFACE LEAK SCENARIO

APPENDIX B

OWMC PHASE 4A - FACTORS FOR SITE SELECTION

TABLE OF CONTENTS

PAGE

B.1 FACTOR USED IN REFINEMENT OF SITE BOUNDARIES B-1

- CONFINING LAYER THICKNESS

B.2 FACTOR USED IN COMPARISON OF ACCESS ROAD AND RAIL ACCESS OPTIONS B-2

- DISTANCE ACROSS HYDROGEOLOGICALLY SENSITIVE LANDS B-5

B.3 FACTOR USED IN COMPARISON OF SITING OPTIONS B-6

- CAPABILITY OF PROVIDING NATURAL CONTAINMENT B-7

B.4 FACTOR USED IN COMPARISON OF SITING OPTIONS B-13

- IMPACT ON GROUND WATER USE B-15

B.1 FACTOR USED IN REFINEMENT OF SITE BOUNDARIES (OWMC PHASE 4A - FACTORS FOR SITE SELECTION)

OWMC PHASE 4A - FACTORS FOR SITE SELECTION

LEAD CONSULTANT:
Gartner Lee Associates Limited

FACTOR GROUPING: Risks Related to Hydrogeologic Suitability	**FACTOR:** Confining Layer Thickness

FACILITY COMPONENTS:
All

FACTORS APPLIED FOR FOLLOWING OPTIONS:

Access Roads	( )	Location of Phys/Chem Treatment Plant	( )
Rail Access	( )	Siting Option Comparison	( )
Refinement of Site Boundaries	(x)	Other	( )

DEFINITION OF FACTOR:
The total thickness of fine-textured materials also known as the confining layer thickness is a general indicator of an area's capability to provide natural containment of contaminants. As the thickness of the confining layer increases, the time required for a contaminant to move downward through the confining layer to underlying permeable materials with aquifer potential (known as the contaminant breakthrough time) also increases. This factor was used in the identification of those portions of individual sites which would provide the longest contaminant breakthrough times.

RATIONALE /SIGNIFICANCE OF FACTOR:
In refinement of site boundaries it would be desireable to identify portions of the site where the confining layer is:

- thickest (provides the greatest containment of potential contaminant) and
- thin or not present (may represents a constraint to development by not providing adequate containment of potential contaminants).

Reference was given to siting facilities over those portions of the site which have the thickest confining layer.

OWMC PHASE 4A - FACTORS FOR SITE SELECTION

FACTOR GROUPING: Risks Related to Hydrogeologic Suitabiity	**FACTOR:** Confining Layer Thickness

INTERPRETATION/METHODOLOGY:
Confining layer thickness maps and geologic cross sections showing confining layer thickness are available for each site.

INDICATORS:

(   ) None specified

DEFINITION: **CONSULTANT:**

RATIONALE/SIGNIFICANCE:

SOURCES OF INFORMATION:
The following sources of information were used:

- published surficial geology maps;
- physical resource constraint mapping; and
- confining layer thickness maps and geologic cross sections prepared as part of this study

INPUT FROM OTHER CONSULTANTS:
Not required

STUDY AREA:
Site

COMMENTS/ASSUMPTIONS/LIMITATIONS:
The available data base (water well records, hydrogeologic and geotechnical borings) varied substantially in completeness and quality from site to site.

B.2 FACTOR USED IN COMPARISON OF ACCESS ROAD AND RAIL ACCESS OPTIONS (OWMC PHASE 4A - FACTORS FOR SITE SELECTION)

OWMC PHASE 4A - FACTORS FOR SITE SELECTION

LEAD CONSULTANT:
Gartner Lee Associates Limited

FACTOR GROUPING: Transportation Risk	**FACTOR:** Distance Through Hydrogeologically Sensitive Lands

FACILITY COMPONENTS:
All

FACTOR APPLIED FOR FOLLOWING OPTIONS:

Access Roads	(x)	Location of Phys/Chem Treatment Plant	( )
Rail Access	(x)	Siting Option Comparison	(x)
Refinement of Site Boundaries	( )	Other	( )

DEFINITION OF FACTOR:
All hydrogeologic considerations which may affect the selection of access road and rail access options are represented by a general "sensitive lands" factor. Geologic/hydrogeologic settings provide different levels of contaminant containment in the event of an accidental spill.

RATIONALE /SIGNIFICANCE OF FACTOR:
In the event of an accidental spill of waste, it is desirable that the natural materials retard the migration of waste contaminants from the area of the spill through the subsurface. This retardation provides sufficient lead time to implement remedial actions. Lands underlain by fine textured soils provide a high degree of natural containment. Lands which are not likely to provide as high a degree of natural containment are defined as "sensitive" and include:

- bedrock at or near surface;
- granular soil at or near surface;
- floodplain deposits (generally variable texture);
- man-made fill (such as granular backfill materials).

OWMC PHASE 4A - FACTORS FOR SITE SELECTION

FACTOR GROUPING: Transportation Risk	**FACTOR:** Distance Through Hydrogeologically Sensitive Lands

INTERPRETATION/METHODOLOGY:
Alternative access roads and rail options were provided by OWMC on 1:50,000 and 1:10,000 scale topographic map bases, respectively. Those segments of the access roads and rail options underlain by "sensitive" lands were identified.

The actual linear distance that the options crossed over sensitive route segments was calculated.

INDICATORS:

( ) None specified

DEFINITION: **CONSULTANT:**

RATIONALE/SIGNIFICANCE:

SOURCES OF INFORMATION:
The following sources of information were used:
- published surficial geology maps;
- physical resource constraint mapping

INPUT FROM OTHER CONSULTANTS:
Not required

STUDY AREA:
Access road and rail access options

OWMC PHASE 4A - FACTORS FOR SITE SELECTION

FACTOR GROUPING:	FACTOR:
Transportation Risk	Distance Through Hydrogeologically Sensitive Lands

COMMENTS/ASSUMPTIONS/LIMITATIONS:
Only readily available published information was used. The published information is generally presented at a 1:50,000 scale. Local conditions may vary from that presented in the mapping.

It is anticipated that an emergency response spill clean-up team will be capable of decommissioning transportation spills promptly.

B.3 FACTOR USED IN COMPARISON OF SITING OPTIONS (OWMC PHASE 4A - FACTORS FOR SITE SELECTION)

OWMC PHASE 4A - FACTORS FOR SITE SELECTION

LEAD CONSULTANT:
Gartner Lee Associates Limited

FACTOR GROUPING: Risks Related to Hydrogeologic Suitability	**FACTOR:** Capability Of Providing Natural Containment

FACILITY COMPONENTS:
All

FACTOR APPLIED FOR FOLLOWING OPTIONS:
Access Roads ( )
Rail Access ( )
Refinement of Site Boundaries ( )
Location of Phys/Chem Treatment Plant ( )
Siting Option Comparison (x)
Other ( )

DEFINITION OF FACTOR:
The "Capability of Providing Natural Containment" factor encompasses those characteristics of the geologic/hydrogeologic environment which influence the migration of potential contaminants. This factor is specifically intended as a measure of the capacity of the environment to naturally retard contaminant movement to underlying aquifers.

RATIONALE /SIGNIFICANCE OF FACTOR:
In keeping with OWMC's goal of minimizing risk to human health the various treatment and disposal facilities are to be located in hydrogeologic settings that provide for the natural restriction of the movement of contaminants.

The physical properties of local geologic materials, the rate and direction of ground water movement, the presence of any man-made structures which may act as pathways for contaminant movement, all influence the natural containment potential of the hydrogeologic setting and were assessed.

OWMC PHASE 4A - FACTORS FOR SITE SELECTION

FACTOR GROUPING:	FACTOR:
Risks Related to Hydrogeologic Suitability	Capability Of Providing Natural Containment

INTERPRETATION/METHODOLOGY:
The interpretation was based on the following:

- information collected during earlier phases;
- data collected as a result of interviews with government agency personnel and local residents;
- geologic data collected during site drilling and site visits; and
- hydrogeologic and geotechnical data on the hydraulic and geotechnical properties of the geologic materials present at the site (information from published and unpublished studies).

INDICATORS:
(1) Predictability of Geologic Condition

DEFINITION:	CONSULTANT:
This indicator is used as a measure of the geologic uniformity of the confining layer present below the individual sites. The confining layer is defined as the uppermost geologic unit(s) of fine-textured, low permeable soil materials through which ground water and contaminant movement rates are predictably slow.	Gartner Lee Associates Limited

RATIONALE/SIGNIFICANCE:
The confining layer should be predictably capable of providing containment in a natural state. Emphasis was placed on establishing the uniformity of the confining layer. The interpretation of uniformity was based on:

- observed lateral and vertical textural consistency in the confining layer in particular the presence of granular zones or lenses; and
- uniform thickness of the confining layer across the site

OWMC PHASE 4A - FACTORS FOR SITE SELECTION

FACTOR GROUPING: Risks related to Hydrogeologic Suitability	**FACTOR:** Capability Of Providing Natural Containment

SOURCES OF INFORMATION:
Information used to establish characteristics of the confining layer include:

- geologic logs provided in water well records and boreholes completed for other hydrogeologic and geotechnical studies; and
- drilling results and field observations.

INPUT FROM OTHER CONSULTANTS:
Not required

STUDY AREA:
Site and site vicinity.

COMMENTS/ASSUMPTIONS/LIMITATIONS:
With the exception of data collected during the drilling program, the data base available for each candidate site varies substantially in completeness and quality from site to site.

OWMC PHASE 4A - FACTORS FOR SITE SELECTION

FACTOR GROUPING:
Risks Related to Hydrogeologic Suitability

FACTOR:
Capability Of Providing Natural Containment

INDICATORS:
(2) Contaminant Breakthrough time

DEFINITION:
"Contaminant Breakthrough time" is defined as the point in time at which a conservative contaminant, such as chloride, moves downward through the confining layer and discharges to the underlying aquifer at a specified concentration. This indicator was used as a measure of the capacity of the confining layer to retard contaminant migration.

CONSULTANT:
Gartner Lee Associates Limited

RATIONALE/SIGNIFICANCE:
Long contaminant breakthrough times are preferred over short times because:

- the time available for contaminant degradation and interaction with geologic materials is maximized;
- the slow rate of contaminant movement allows more time for the implementation of remedial measures should they be required; and
- if it is necessary to remove contaminated soils such as during the decommissioning of the treatment plants, the slow rate of contaminant movement would result in a smaller volume of soil to be excavated.

OWMC PHASE 4A - FACTORS FOR SITE SELECTION

FACTOR GROUPING: Risks related to Hydrogeologic Suitability	**FACTOR:** Capability Of Providing Natural Containment

SOURCES OF INFORMATION:
Impact predictions incorporated geologic data obtained during site drilling. Information on the hydraulic properties of the geologic materials was obtained from published and unpublished studies.

INPUT FROM OTHER CONSULTANTS:
Preliminary facility design information and proposed facility layouts were obtained from the engineering consultant - Monenco Limited.

STUDY AREA:
Site and site vicinity.

COMMENTS/ASSUMPTIONS/LIMITATIONS:
Contaminant breakthrough times are sensitive to changes in the parameters to be used in the calculations including confining layer hydraulic conductivity, porosity, thickness and hydraulic gradient through the layer. With the exception of confining layer thickness which would be measured at the boreholes, the other parameters were based on the interpretation of geologic conditions.

OWMC PHASE 4A - FACTORS FOR SITE SELECTION

FACTOR GROUPING: Risks Related to Hydrogeologic Suitability	**FACTOR:** Capability Of Providing Natural Containment

INDICATORS:
(3) Other Contaminant Pathways

DEFINITION: Man-made structures including existing and abandoned wells (both water and petroleum), drainage tiles and permeable backfill materials may provide potential pathways for contaminant migration. The significance of these activities and features on site development will need to be addressed on a site specific basis.	**CONSULTANT:** Gartner Lee Associates Limited

RATIONALE/SIGNIFICANCE:
Abandoned wells, drainage tiles, permeable backfill material may act as pathways for contaminants and are not likely to restrict movement. Engineering measures are available which can be implemented prior to site operation to alleviate these potential concerns.

OWMC PHASE 4A - FACTORS FOR SITE SELECTION

FACTOR GROUPING: Risks related to Hydrogeologic Suitability	**FACTOR:** Capability Of Providing Natural Containment

SOURCES OF INFORMATION:

- oil and gas well records maintained on file by the Ministry of Natural Resources;
- water well records maintained on file by the Ministry of the Environment
- "walk and talk" survey sheets; and
- field survey work.

INPUT FROM OTHER CONSULTANTS:
Not required

STUDY AREA:
Site and site vicinity.

COMMENTS/ASSUMPTIONS/LIMITATIONS:
It may not be possible to identify all features. Historical records may not exist or have been lost. Other features are buried and may not be readily documentable and will only be obvious during site selection.

B.4 FACTOR USED IN COMPARISON OF SITING OPTIONS (OWMC PHASE 4A - FACTORS FOR SITE SELECTION)

OWMC PHASE 4A - FACTORS FOR SITE SELECTION

LEAD CONSULTANT:
Gartner Lee Associates Limited

FACTOR GROUPING: Risks Related to Hydrogeologic Suitability	**FACTOR:** Impact on Ground Water Use

FACILITY COMPONENTS:
All

FACTOR APPLIED FOR FOLLOWING OPTIONS:
Access Roads ☐
Rail Access ☐
Refinement of Site Boundaries ☐
Location of Phys/Chem Treatment Plant ☐
Siting Option Comparison ☒
Other ☐

DEFINITION OF FACTOR:
All considerations specific to local ground water resources are represented by a general "Impact On Ground Water Use" factor. This factor encompasses the characteristics of the resource (productivity of aquifer and water quality), uses of the resource, the existence of alternative water supplies, regulatory policy respecting ground water protection and the ability of the resource to provide contaminant dilution.

RATIONALE /SIGNIFICANCE OF FACTOR:
Ground water is used extensively in rural areas as a source of water supply for domestic and agricultural purposes. In order to assess the significance of facility siting on local ground water resources, it was necessary to identify existing and anticipated future ground water uses, the characteristics (i.e. productivity and water quality) of the ground water resource and the availability of alternative water supplies. Regulatory policy respecting protection of ground water resources would need to be identified, as would information on the ability of the resource to provide dilution in the event contaminants are introduced into the aquifer. Using this information, it was possible to evaluate the resource with respect to

- use;
- quantity and quality; and
- availability

Following the evaluation of this resource it was possible to develop strategies aimed at minimizing risks to ground water users.

OWMC PHASE 4A - FACTORS FOR SITE SELECTION

FACTOR GROUPING: Risks Related to Hydrogeologic Suitability	**FACTOR:** Impact on Ground Water Use

INTERPRETATION/METHODOLOGY:
All ground water resource information available for each of the candidate sites was be collected and evaluated to establish the physical characteristics of the resources and its use for local water supply purposes. The individual candidate sites were compared based on the perceived significance of the resource, the availability of alternative water supplies and the ability of the resource to provide contaminant dilution.

INDICATORS:

(1) Available Dilution in Aquifer

DEFINITION: This indicator was introduced to provide a qualitative assessment of the potential for contaminant dilution in the principal aquifer(s) present below each of the candidate sites.	**CONSULTANT:** Gartner Lee Associates Limited

RATIONALE/SIGNIFICANCE:
Some contaminants such as nonreactive ions (e.g. chloride) and persistent organic compounds, are relatively unaffected by attenuation processes and may only be reduced in concentration by dilution. Dilution in the subsurface occurs where the contaminants spread out from the flow path as a result of mechanical dispersion and molecular diffusion.

SOURCES OF INFORMATION:
Information used included:

- ground water use information collected during the "walk and talk" survey;
- water well records; and
- published and unpublished studies.

OWMC PHASE 4A - FACTORS FOR SITE SELECTION

FACTOR GROUPING: Risks Related To Hydrogeologic Suitability	**FACTOR:** Impact on Ground Water Use

INPUT FROM OTHER CONSULTANTS:
Information on expected contaminants and likely volumes and concentrations are required from the engineering consultant - Monenco Limited.

STUDY AREA:
Site and site vicinity

COMMENTS/ASSUMPTIONS/LIMITATIONS:
It was not possible to obtain the necessary data on the characteristics of local aquifers and on expected contaminants which may potentially be released from the various facilities.

It is also possible that contaminant movement even following dilution in the aquifer may result in some degradation of the local ground water quality. The significance of such degradation would need to be addressed on a site by site basis. Regulatory input would be required.

OWMC PHASE 4A - FACTORS FOR SITE SELECTION

FACTOR GROUPING:	FACTOR:
Risks Related to Hydrogeologic Suitability	Impact on Ground Water Use

INDICATORS:

(2) Availability of Alternative Ground Water Supplies

DEFINITION:	CONSULTANT:
This indicator has been introduced to establish the existence of alternative ground water supplies in the event that the current principal source of supply at each site is contaminated and can no longer be used. An alternative supply is defined as a communal well capable of providing an adequate supply of water, equal to or better in quality than the supply to be replaced.	Gartner Lee Associates Limited

RATIONALE/SIGNIFICANCE:
Alternative ground water sources would need to be:
(a) hydrogeologically isolated from both the source of contamination and the original source of supply which could become contaminated; or
(b) sufficiently removed from the contaminated area so that any potential impacts would be negligible.

The alternative source should also be within a reasonable distance from the location where it would be required to reduce water transportation costs.

SOURCES OF INFORMATION:
Information used included:
- ground water use information collected during the "walk and talk" survey;
- water well records; and
- published and unpublished studies.

OWMC PHASE 4A - FACTORS FOR SITE SELECTION

FACTOR GROUPING: Risks Related to Hydrogeologic Suitability	**FACTOR:** Impact on Ground Water Use

INPUT FROM OTHER CONSULTANTS:
Not required

STUDY AREA:
Site vicinity

COMMENTS/ASSUMPTIONS/LIMITATIONS:
Information on local ground water resources varied from site to site.

The degree of isolation from the contaminated well and the practicality of developing alternative ground water supplies would need to be addressed on a site-by-site basis. Similarly, future consideration of alternative supplies, where required, should also address the availability of other sources of supply such as hauled water and municipal services.

OWMC PHASE 4A - FACTORS FOR SITE SELECTION

FACTOR GROUPING: Risks Related to Hydrogeologic Suitability	**FACTOR:** Impact on Ground Water Use

INDICATORS:

(3) Existing use and potential demand

DEFINITION: Ground water is used extensively in rural parts of Ontario as a source of water supply. The extent of use is dependent primarily on aquifer characteristics (well productivity and quality) and availability of alternative water sources such as municipal services and surface water supplies	**CONSULTANT:** Gartner Lee Associates Limited

RATIONALE/SIGNIFICANCE:
The identification of current and projected future uses of ground water is necessary for the assessment of the importance of the resource and would be required in establishing the significance of potential impacts resulting from facilities development.

SOURCES OF INFORMATION:
- previously collected reports and maps on ground water resources;
- water well information from MOE, water well records and "walk and talk" survey sheets;
- "Permit to Take Water" forms (MOE).

OWMC PHASE 4A - FACTORS FOR SITE SELECTION

FACTOR GROUPING: Risks Related To Hydrogeologic Suitability	**FACTOR:** Impact on Ground Water Use

INPUT FROM OTHER CONSULTANTS:
Not required

STUDY AREA:
Site and site vicinity

COMMENTS/ASSUMPTIONS/LIMITATIONS:
None

APPENDIX C

BASE MAPS SHOWING REFINED BOUNDARIES, ACCESS ROAD OPTIONS AND RAIL ACCESS OPTIONS

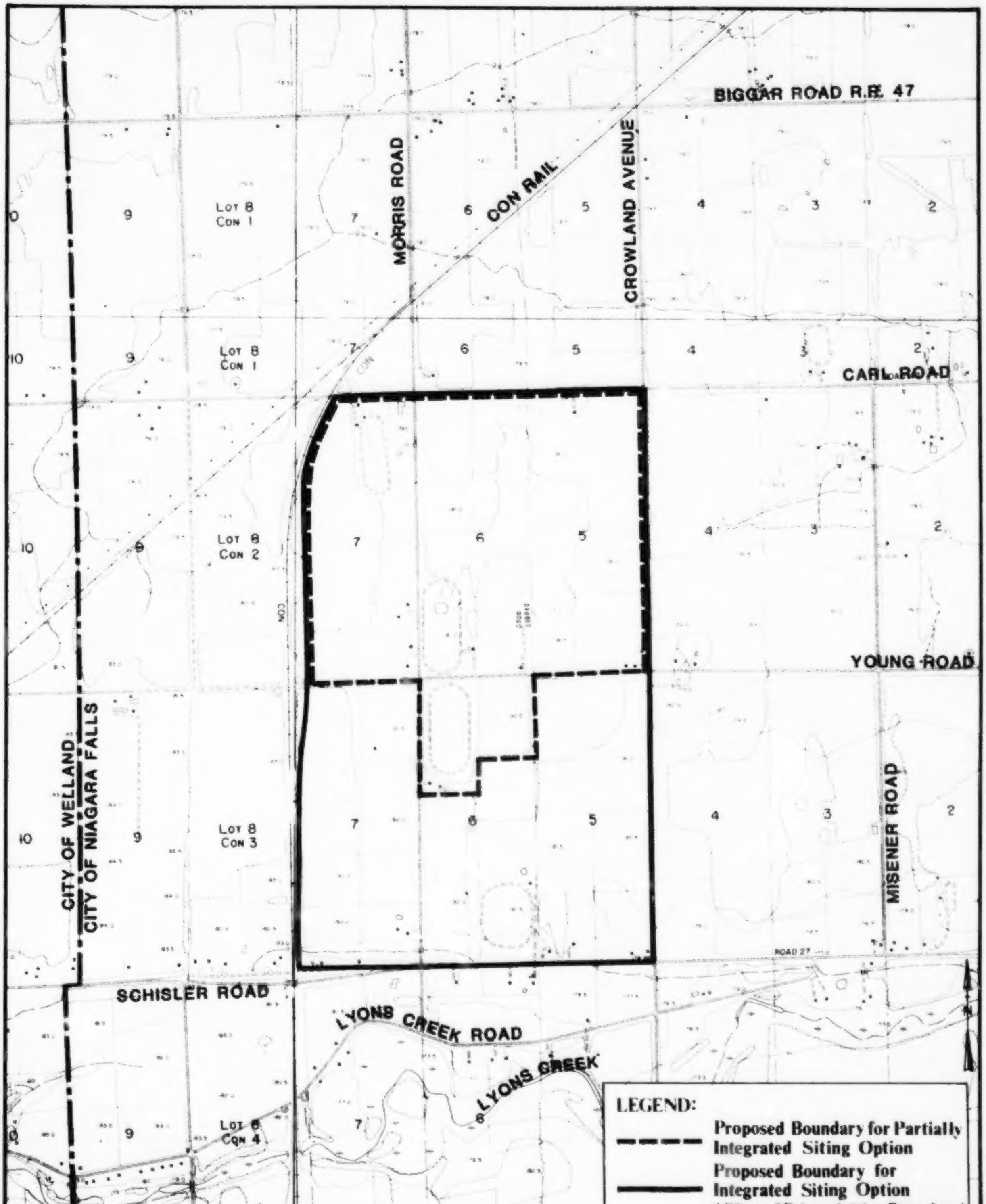
TABLE OF CONTENTS

PAGE

C1 - REFINEMENT OF SITE BOUNDARIES - LF-1E C-1
C2 - REFINEMENT OF SITE BOUNDARIES - LF-3C C-2
C3 - REFINEMENT OF SITE BOUNDARIES - PI-1N C-3

C4 - PHASE 4A ACCESS ROADS - LF-3C C-4
C5 - PHASE 4A ACCESS ROADS - LF-9C C-4
C6 - PHASE 4A ACCESS ROADS - LF-1E C-6
C7 - PHASE 4A ACCESS ROADS - LF-1E/PI-27E, TO PI-27E C-7
C8 - PHASE 4A ACCESS ROADS - LF-1E/PI-27E, PI-27E TO LF-1E C-8
C9 - PHASE 4A ACCESS ROADS - LF-2N/PI-1N, TO PI-1N C-9
C10 - PHASE 4A ACCESS ROADS - LF-2N/PI-1N, PI-1N TO LF-2N C-10
C11 - PHASE 4A ACCESS ROADS - LF-2N/PI-13N, TO PI-13N C-11
C12 - PHASE 4A ACCESS ROADS - LF-2N/PI-13N, PI-13N TO LF-2N C-12
C13 - PHASE 4A ACCESS ROADS - LF-4N/PI-1N, TO LF-4N C-13
C14 - PHASE 4A ACCESS ROADS - LF-4N/PI-1N, PI-1N TO LF-4N C-14
C15 - PHASE 4A ACCESS ROADS - LF-4N/PI-13N, PI-13N TO LF-4N C-15

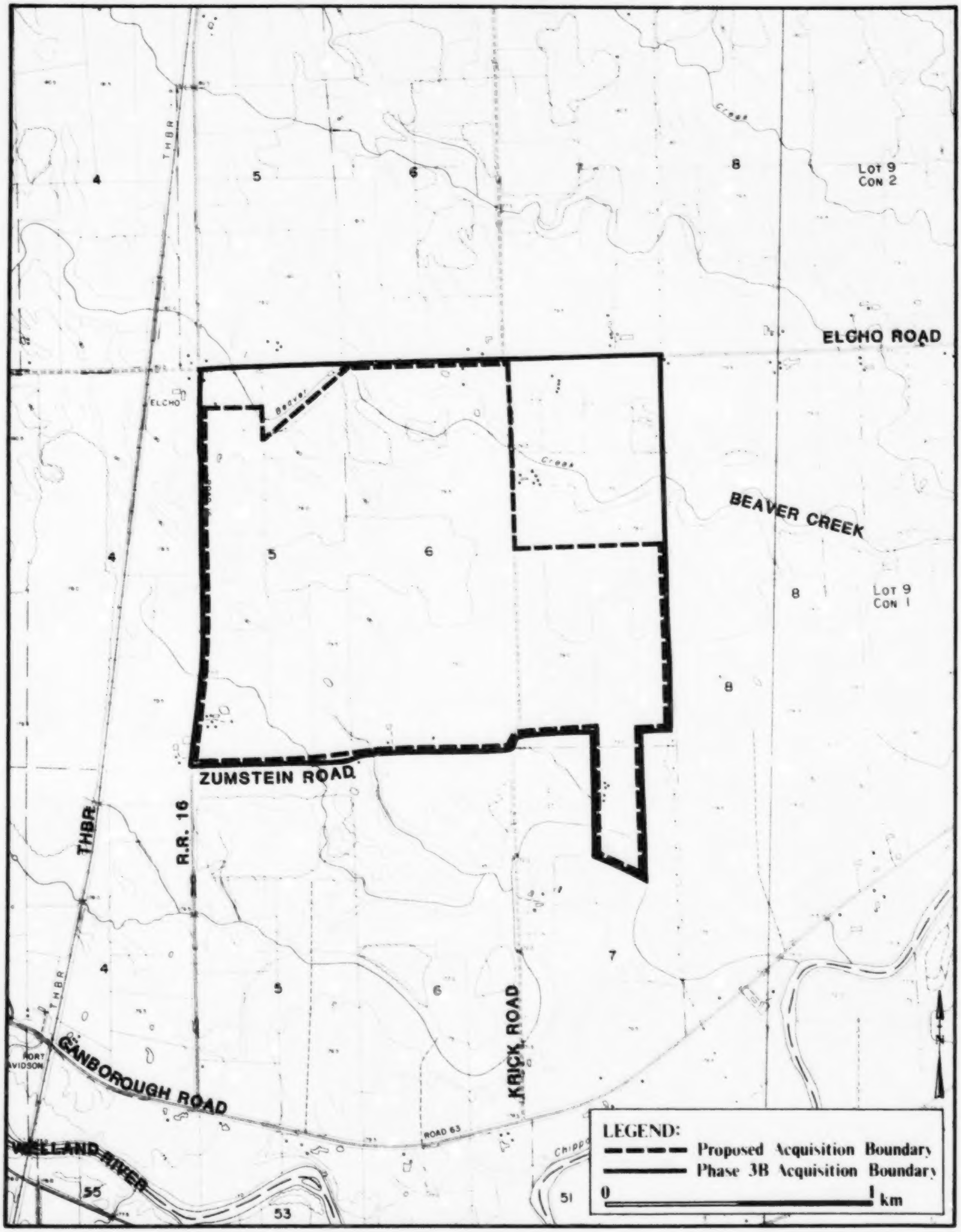
C16 - RAIL ACCESS - LF-3C C-16
C17 - RAIL ACCESS - LF-9C C-17
C18 - RAIL ACCESS - LF-1E C-18
C19 - RAIL ACCESS - PI-27E C-19
C20 - RAIL ACCESS - LF-4N C-20
C21 - RAIL ACCESS - PI-1N C-21



LF-1E

REFINEMENT OF SITE BOUNDARIES

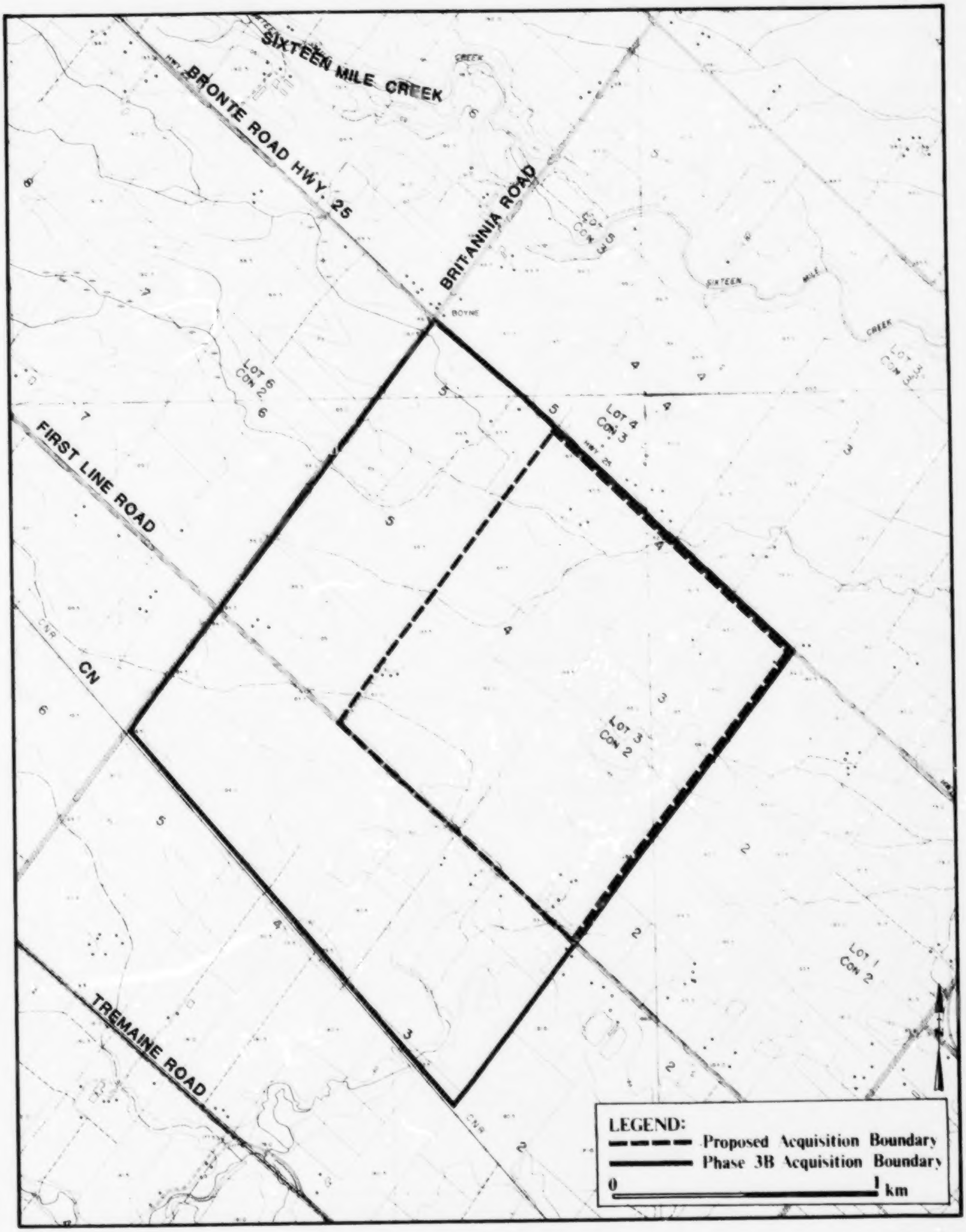
FIGURE C1



LF-3C

REFINEMENT OF SITE BOUNDARIES

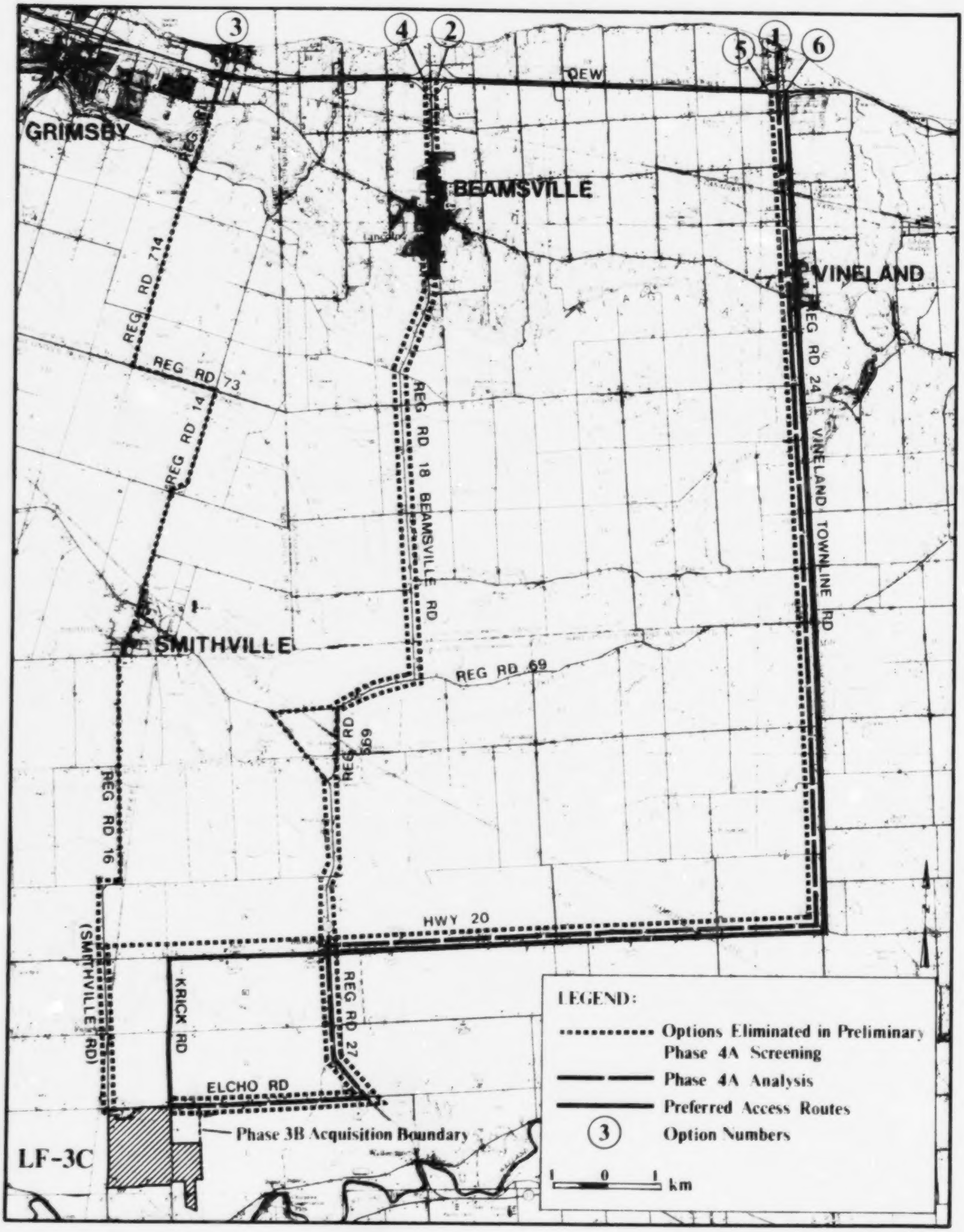
FIGURE C 2



PI-1N

REFINEMENT OF SITE BOUNDARIES

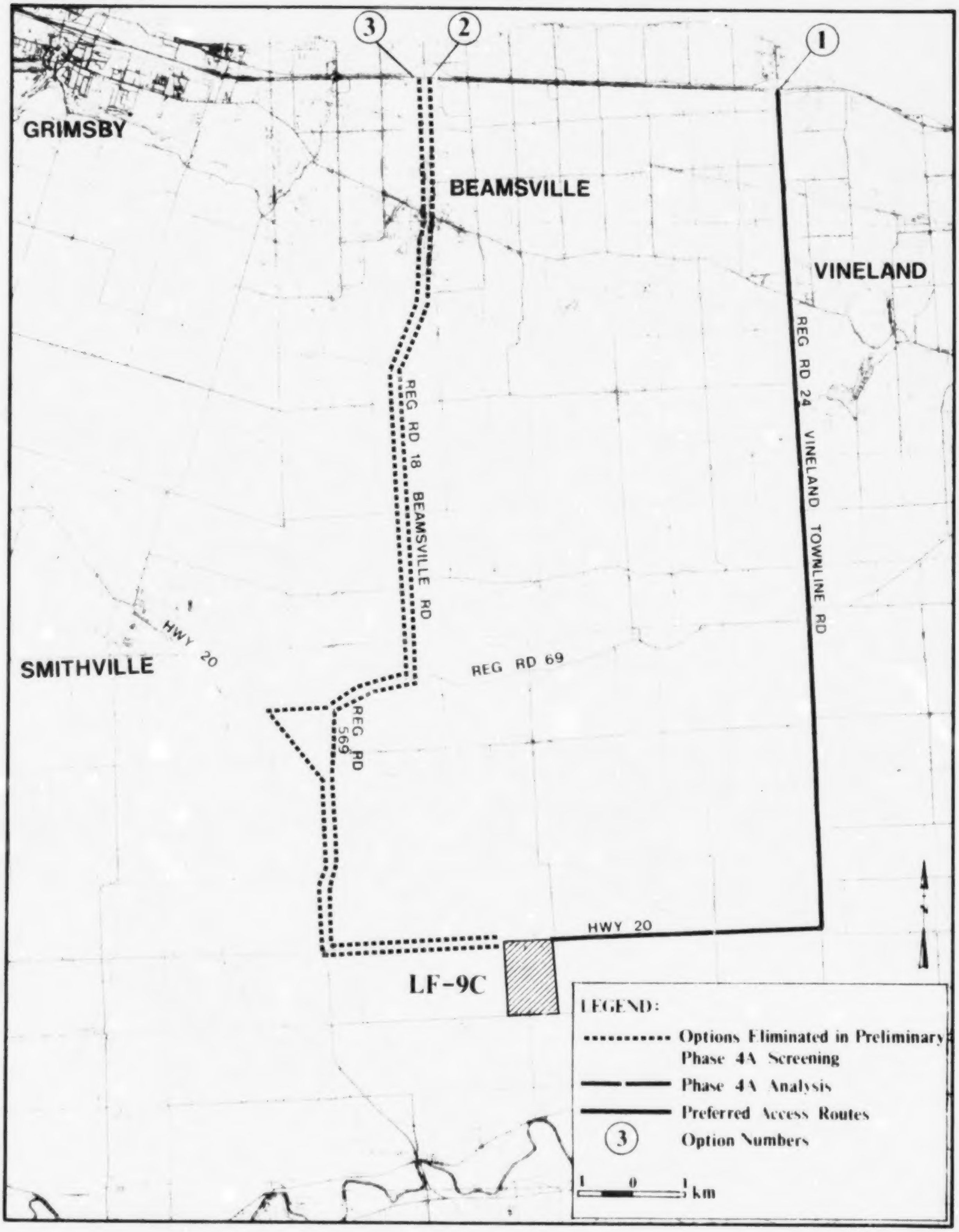
FIGURE C3



LF-3C

PHASE 4A ACCESS ROADS

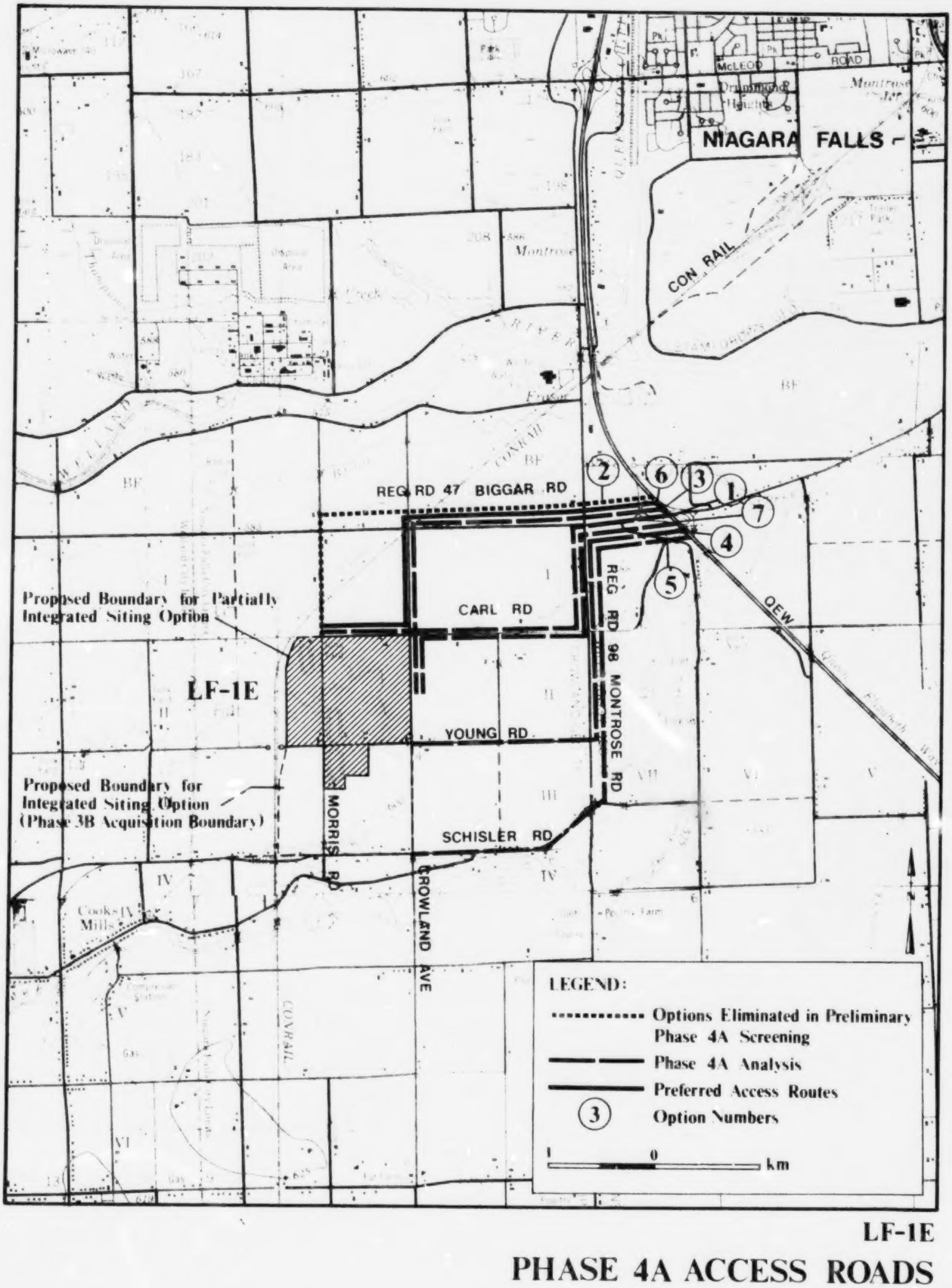
FIGURE C4



LF-9C

PHASE 4A ACCESS ROADS

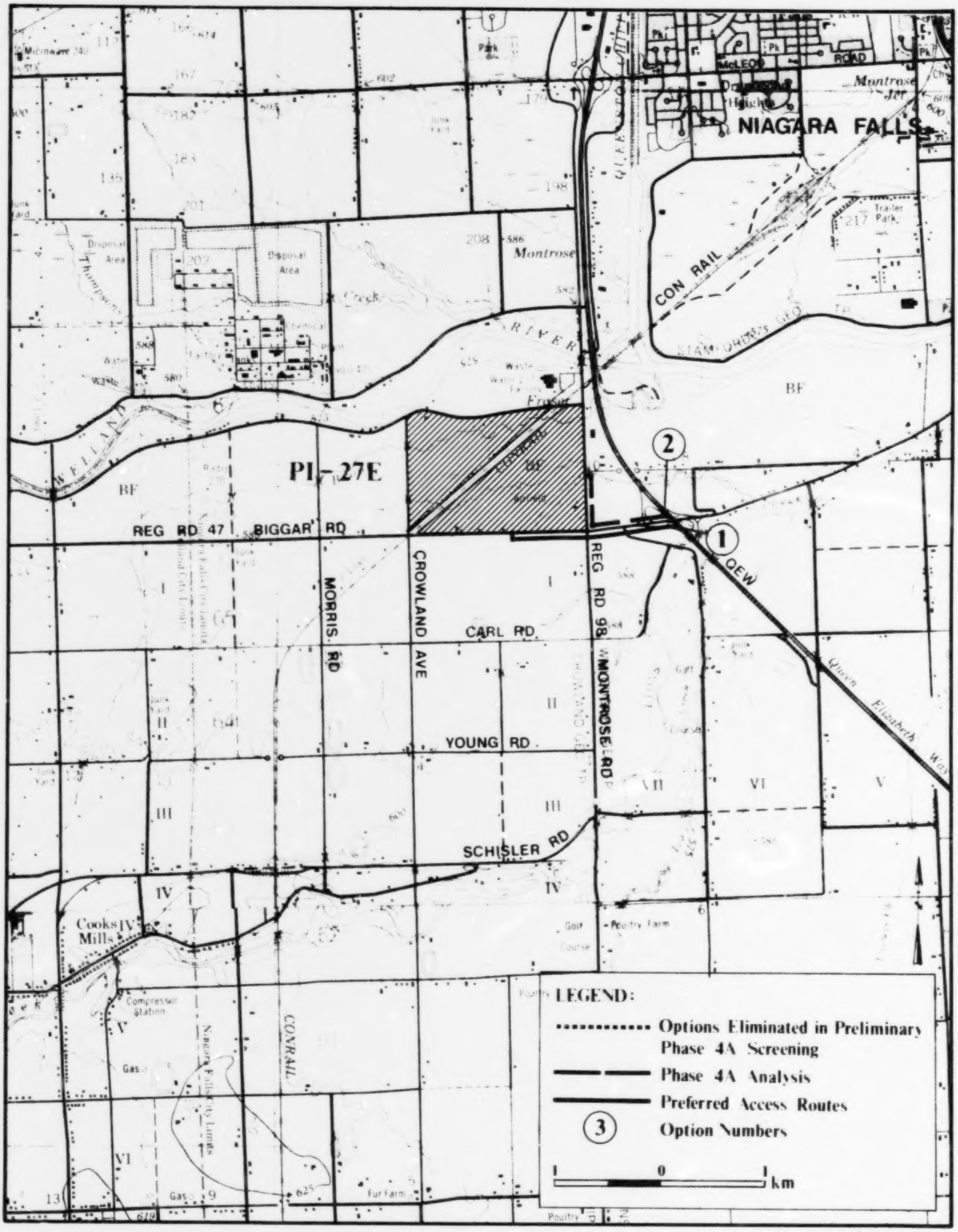
FIGURE C5



LF-1E

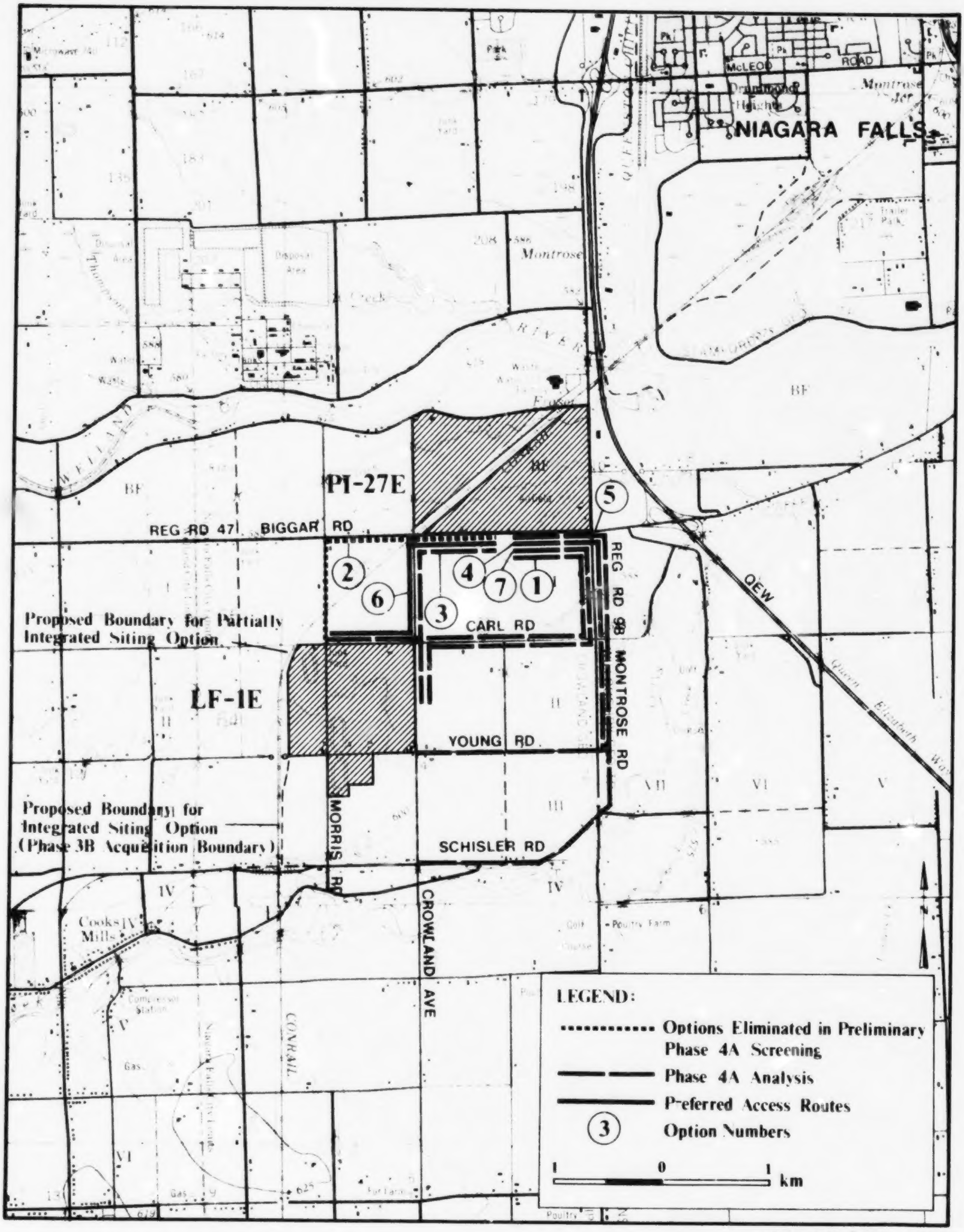
PHASE 4A ACCESS ROADS

FIGURE C6



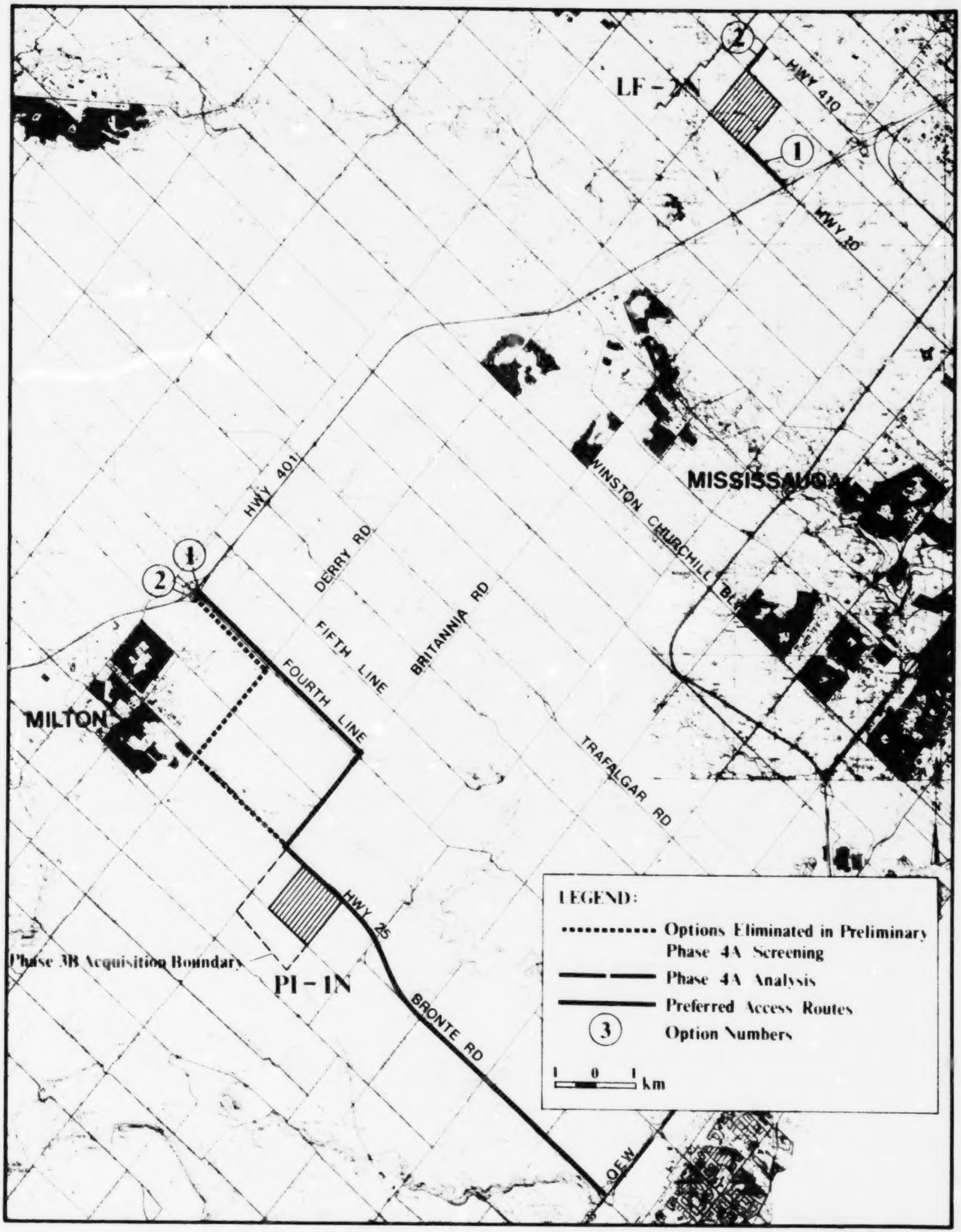
LF-1E /PI-27E
TO PI-27E
PHASE 4A ACCESS ROADS

FIGURE C7



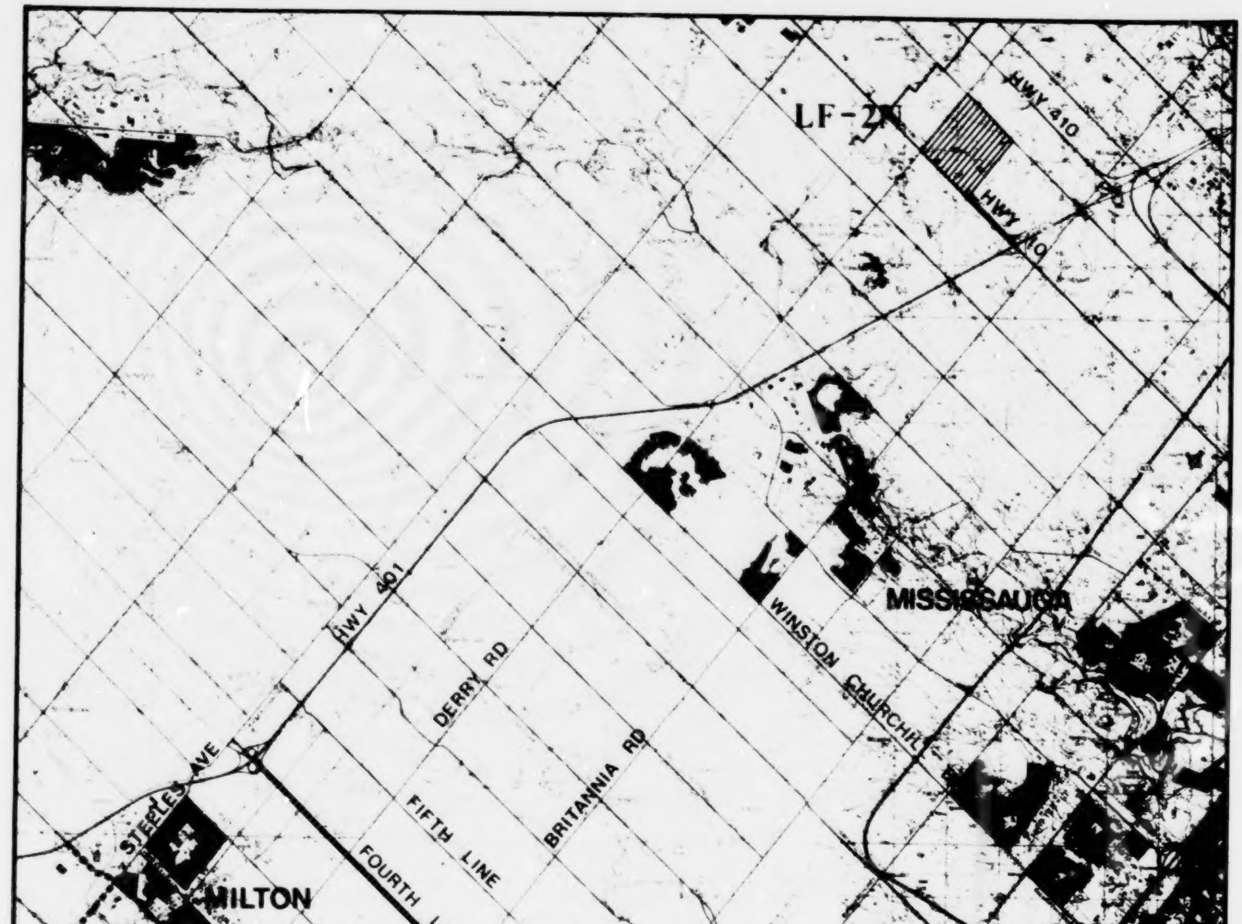
LF-1E/ PI-27E
PI – 27E TO LF – 1E
PHASE 4A ACCESS ROADS

FIGURE C 8



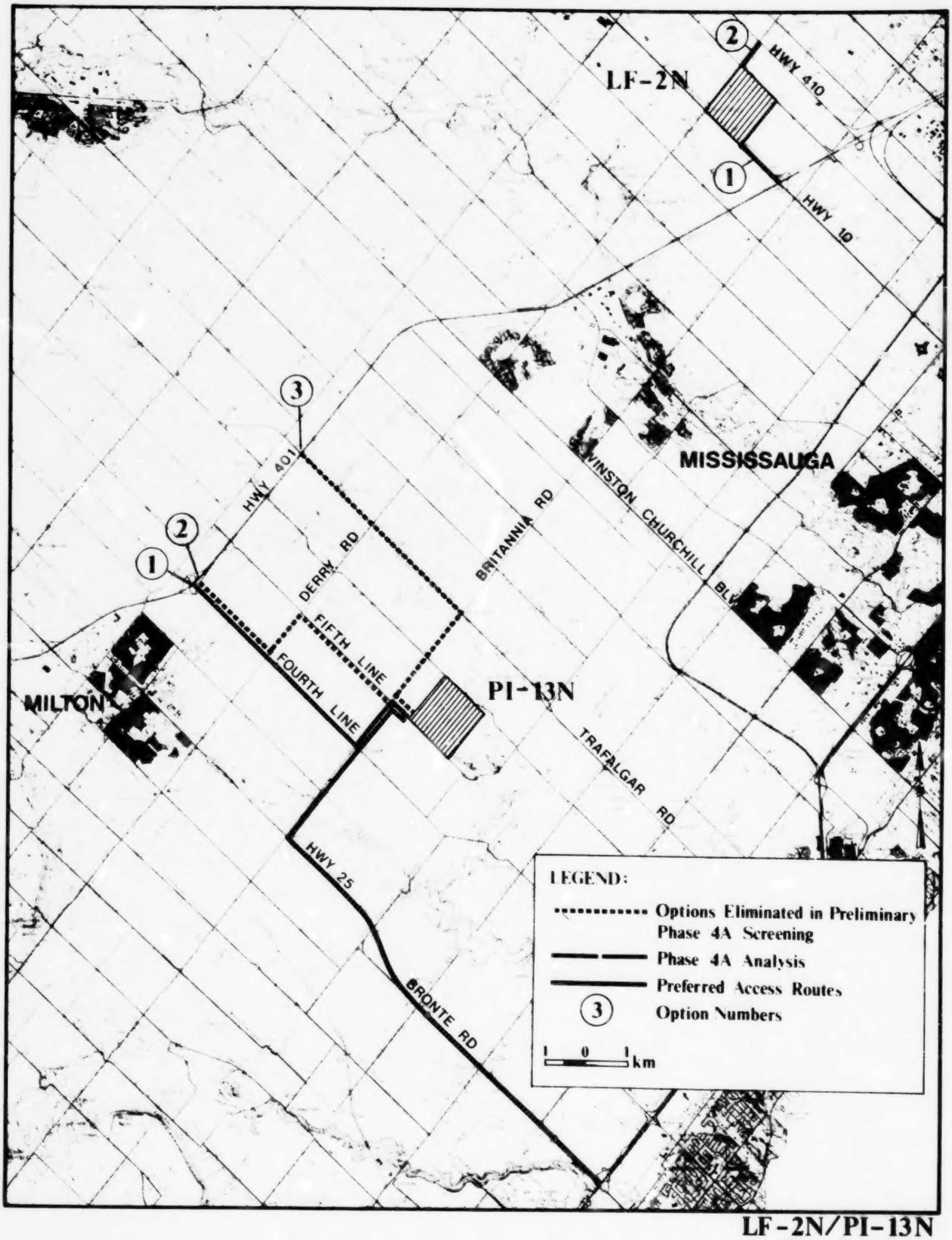
LF-2N/PI-1N
TO PI-1N
PHASE 4A ACCESS ROADS

FIGURE C 9



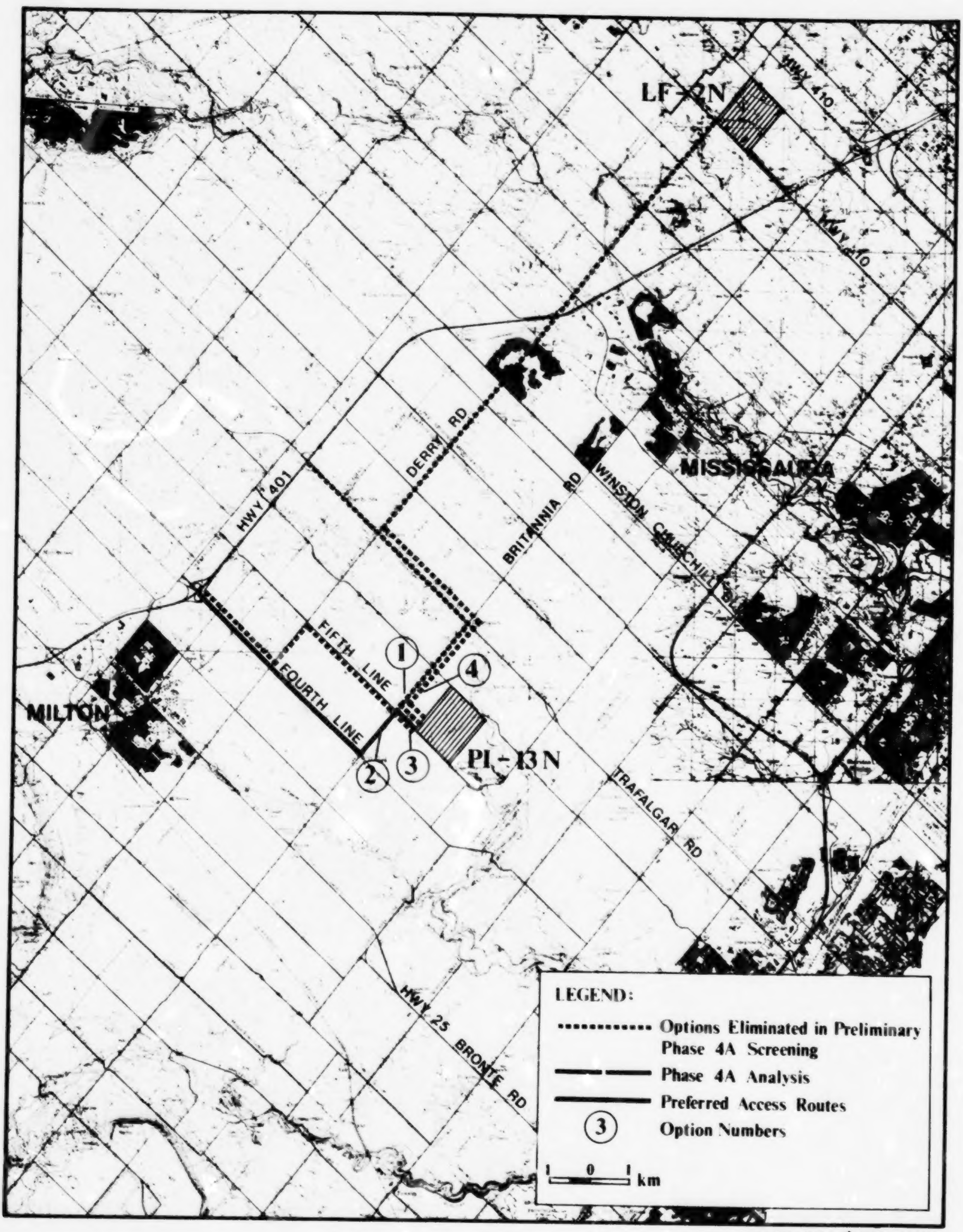
LF-2N/PI-1N
PI-1N TO LF-2N
PHASE 4A ACCESS ROADS

FIGURE C10



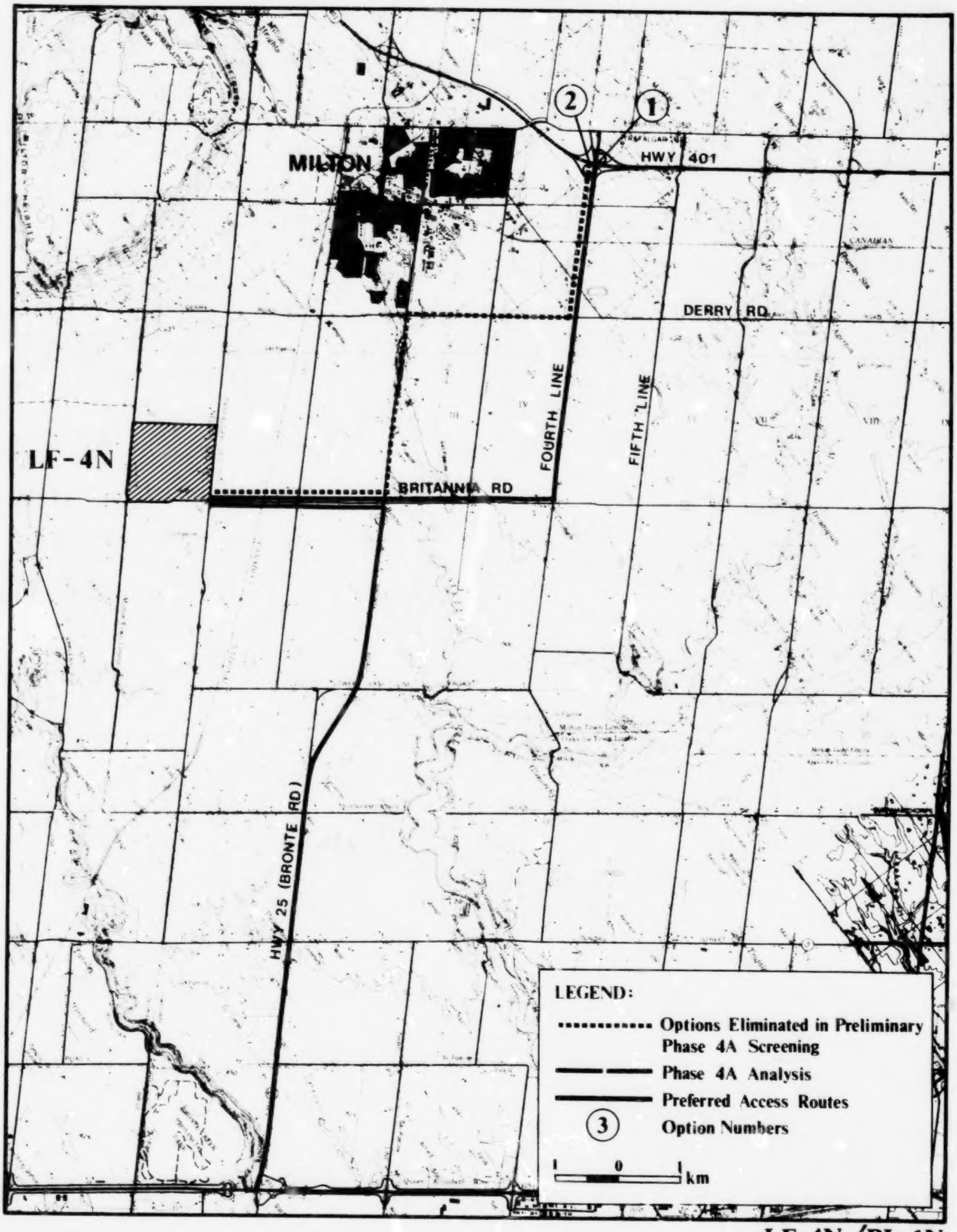
LF-2N/PI-13N
TO PI-13N
PHASE 4A ACCESS ROADS

FIGURE C11



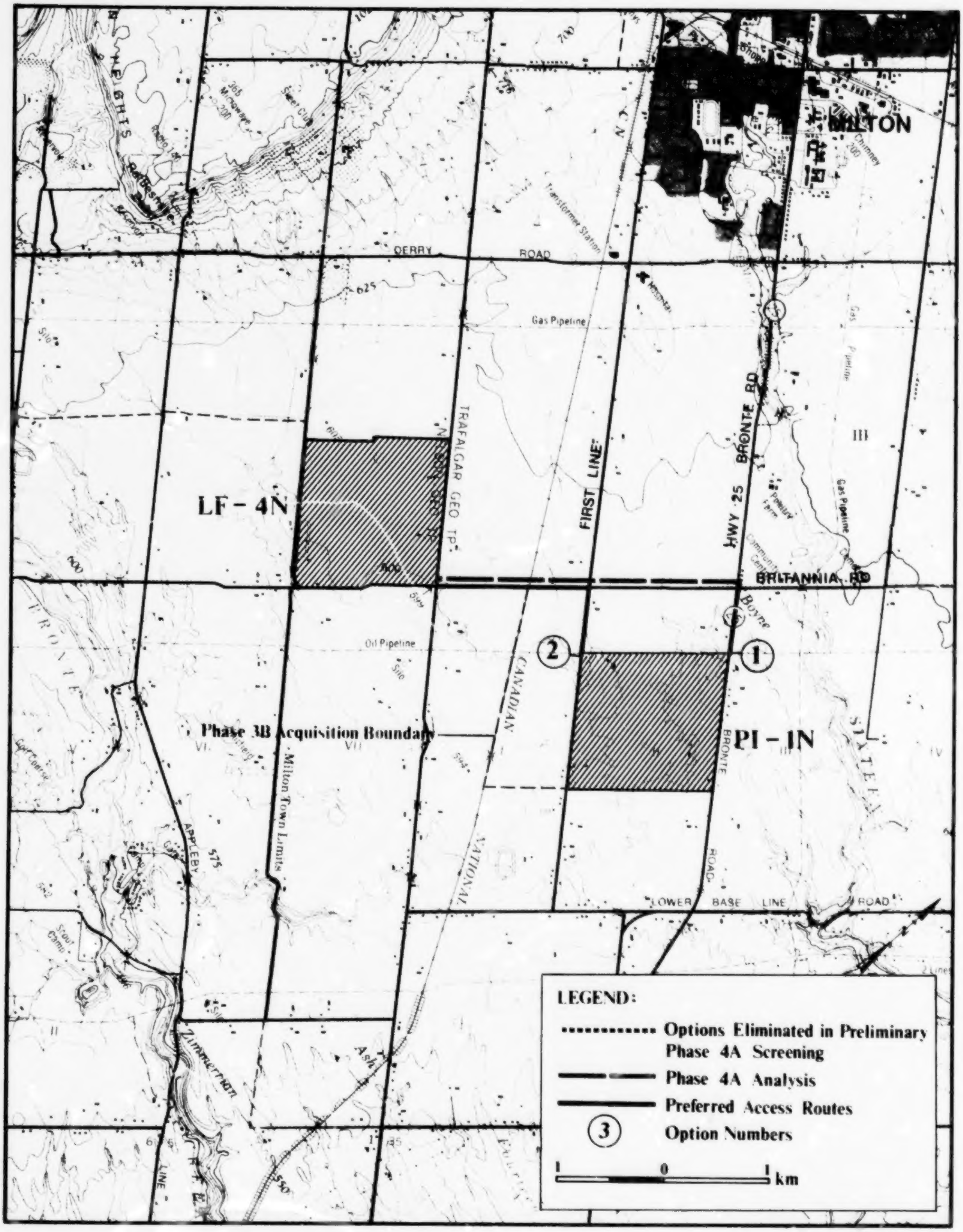
LF-2N/ PI-13N
PI-13N TO LF-2N
PHASE 4A ACCESS ROADS

FIGURE C12



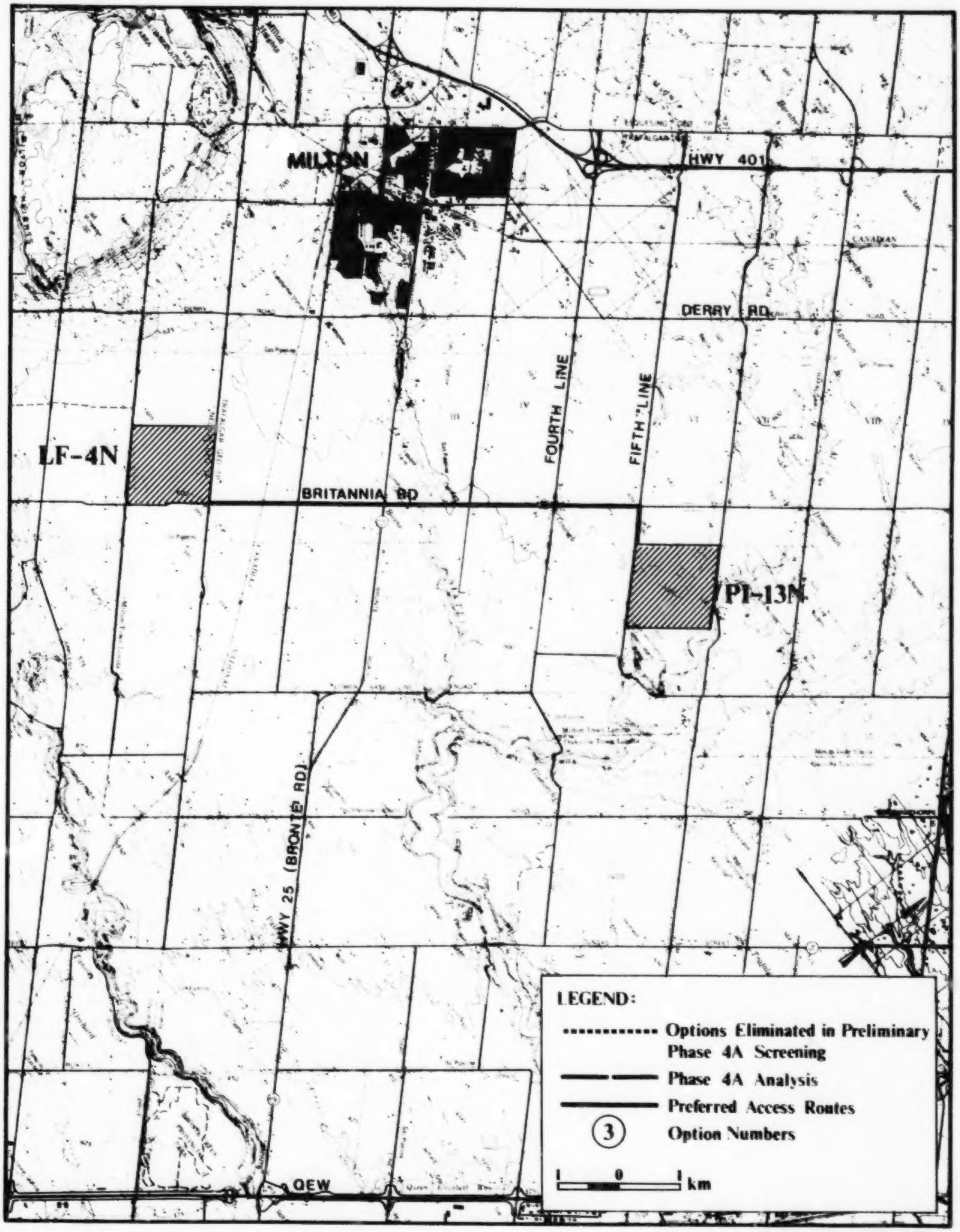
LF-4N /PI-1N
TO LF-4N
PHASE 4A ACCESS ROADS

FIGURE C13



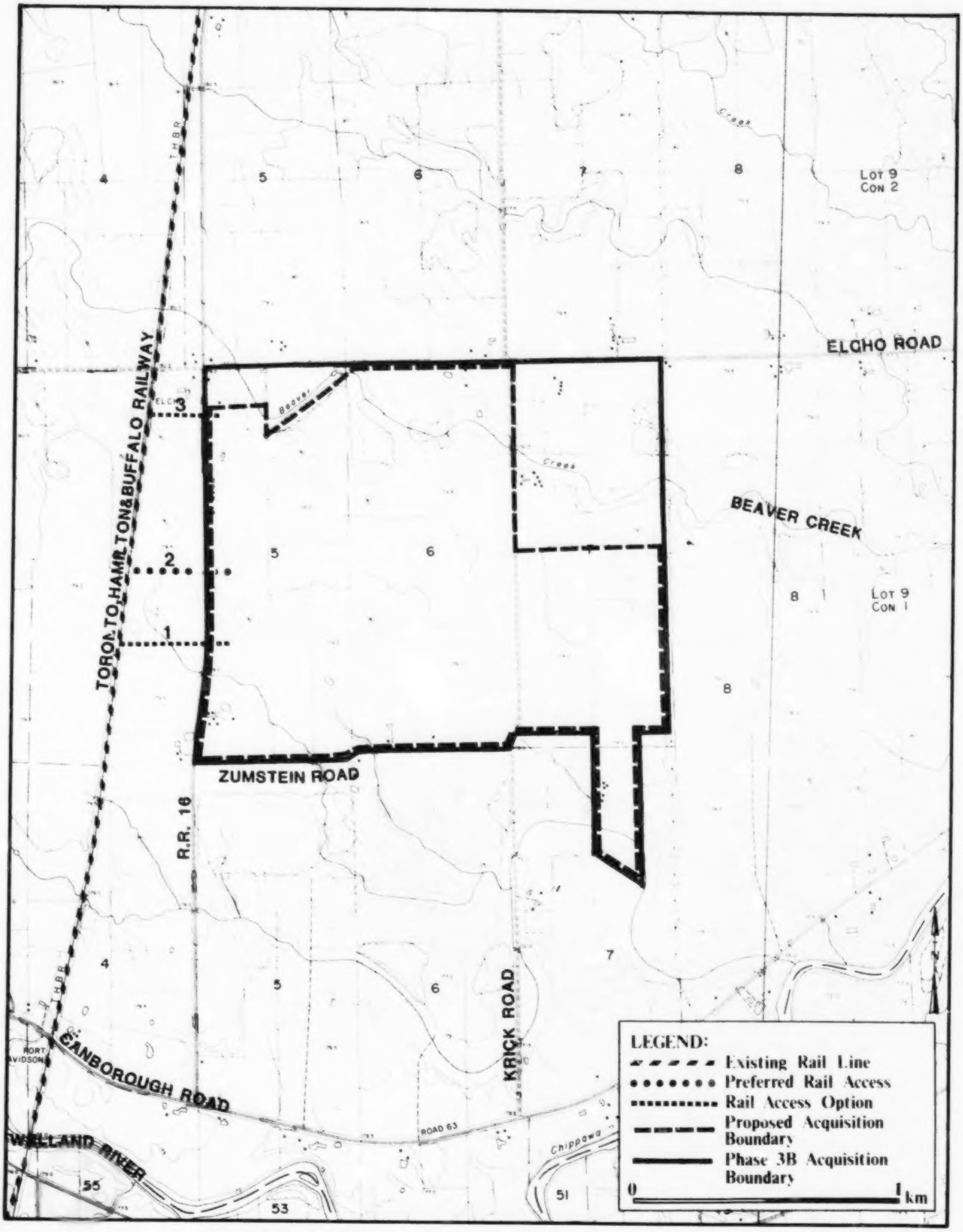
LF-4N/ PI-1N
PI - 1N TO LF-4N
PHASE 4A ACCESS ROADS

FIGURE C14



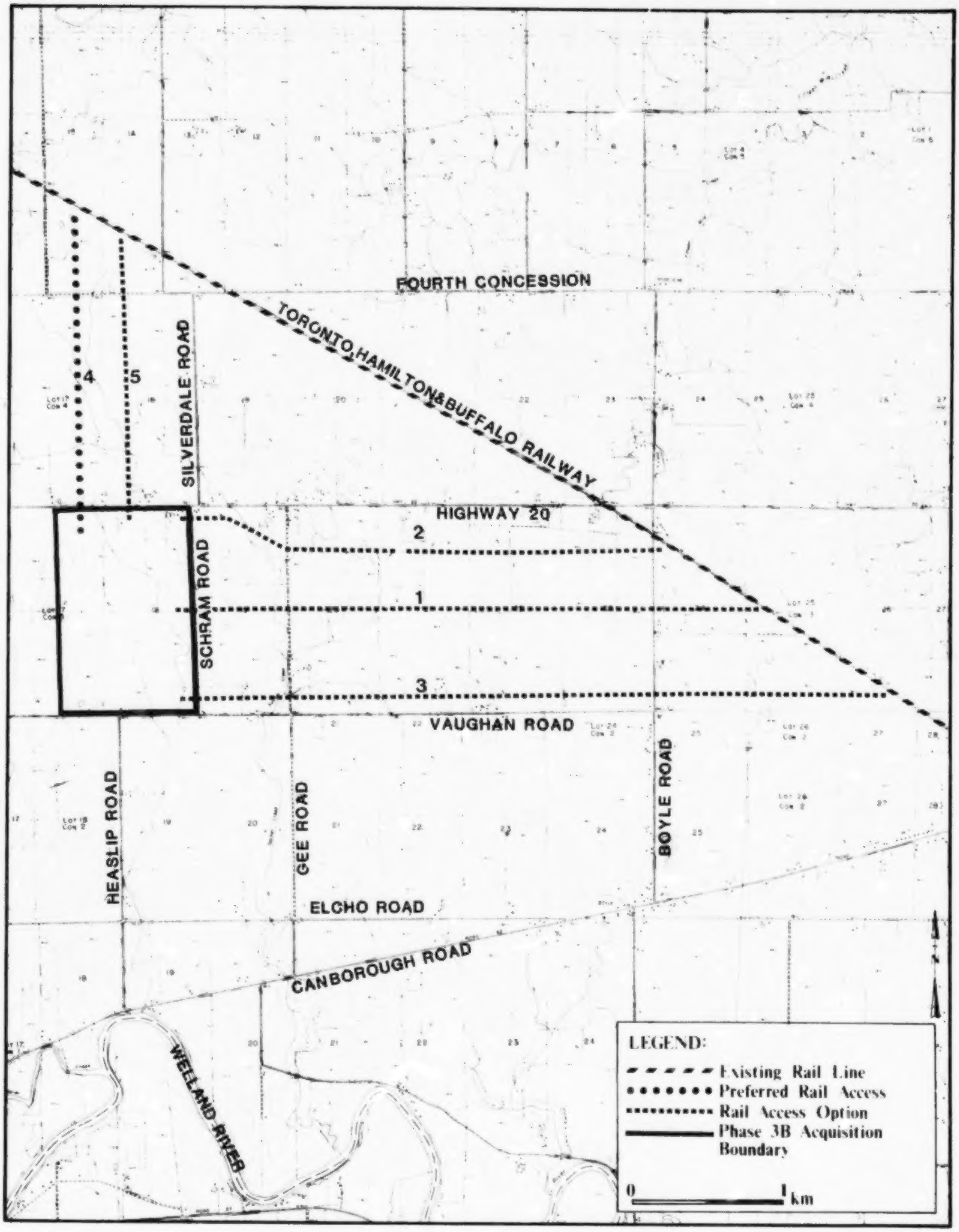
LF-4N/ PI-13N
PI-13N TO LF-4N
PHASE 4A ACCESS ROADS

FIGURE C15



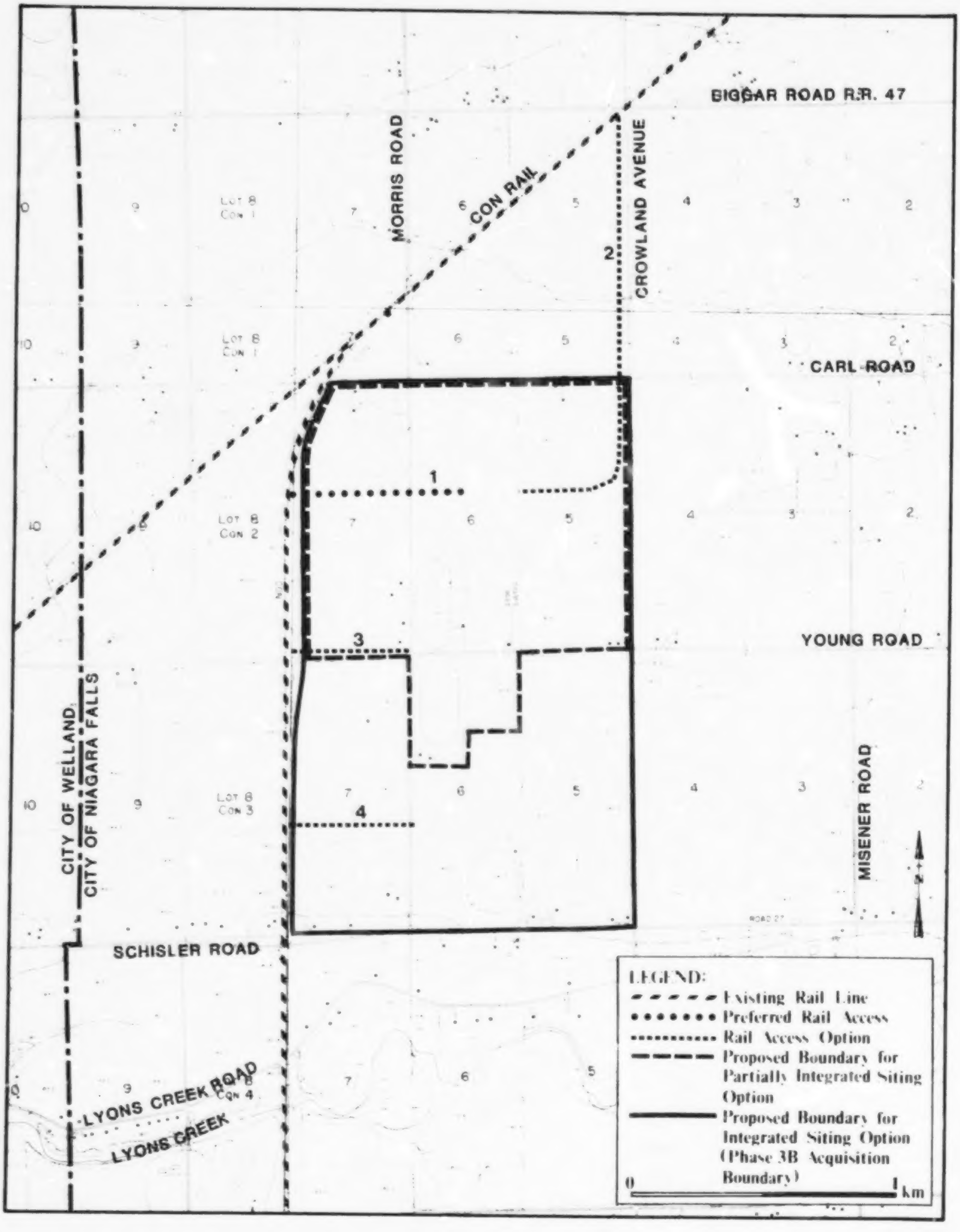
LF-3C
RAIL ACCESS

FIGURE C 16



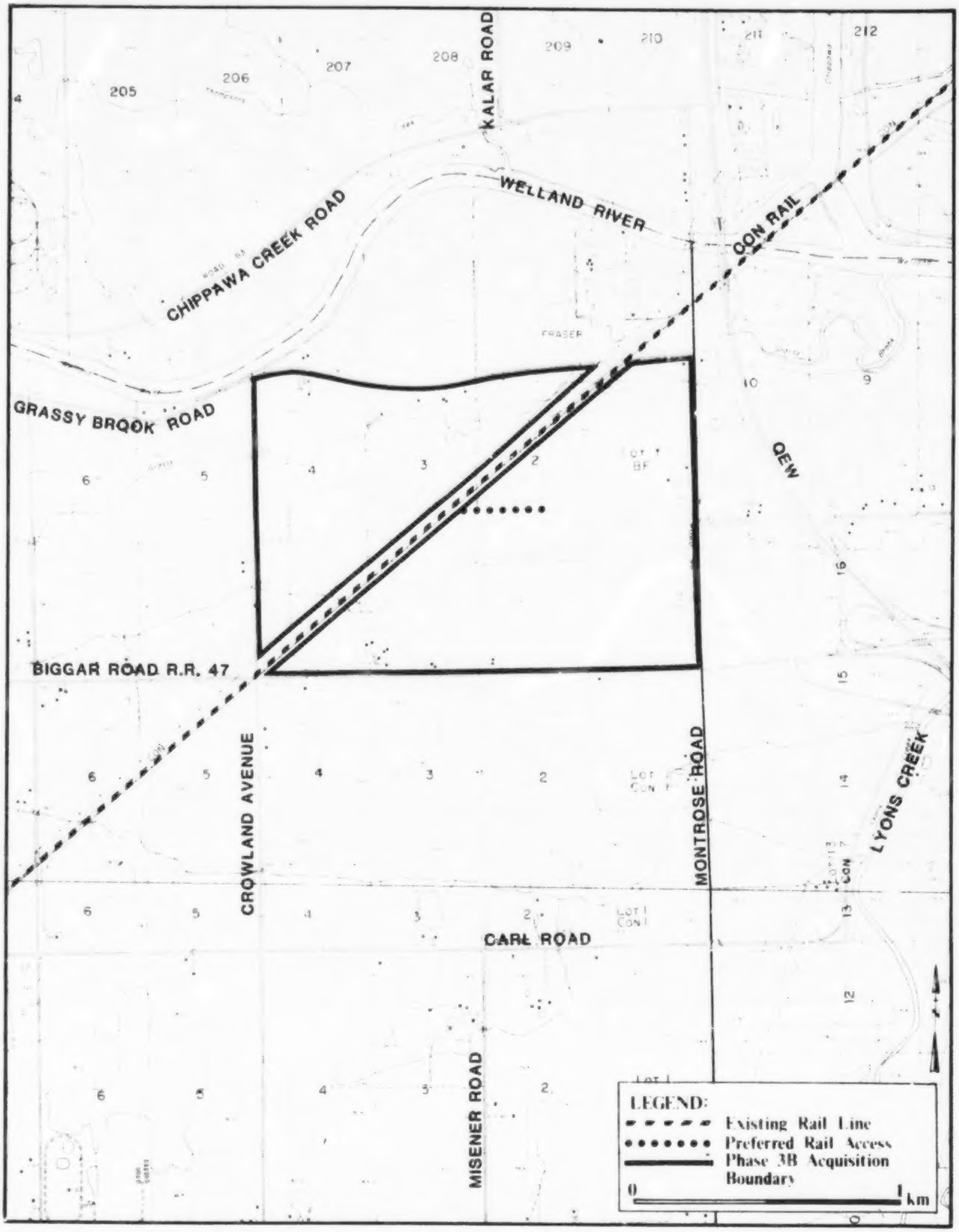
LF-9C
RAIL ACCESS

FIGURE C17



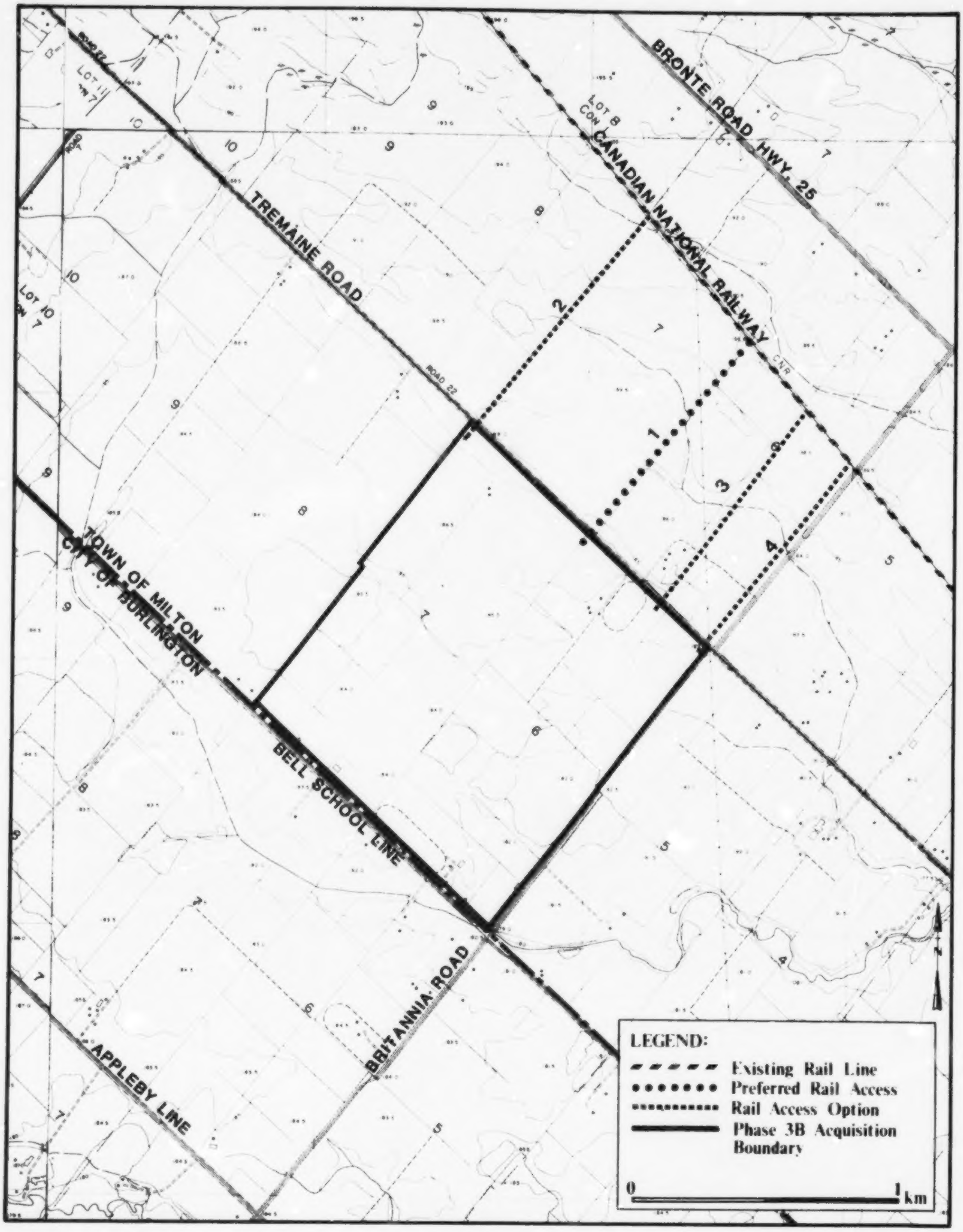
LF-1E
RAIL ACCESS

FIGURE C 18

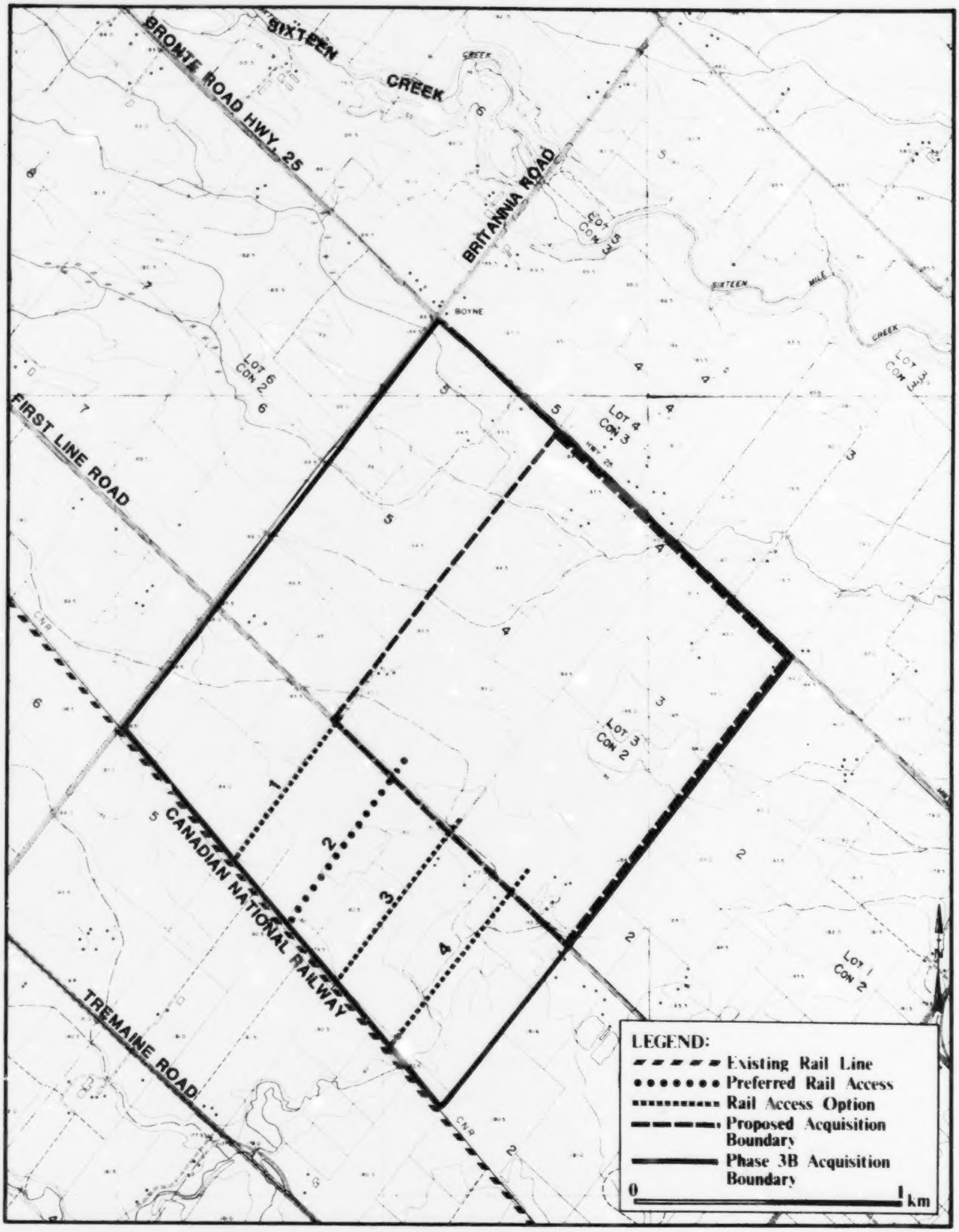


PI-27E
RAIL ACCESS

FIGURE C 19



LF-4N
RAIL ACCESS
FIGURE C20



PI-1N
RAIL ACCESS

FIGURE C 21

APPENDIX D

DATA MATRICES

TABLE OF CONTENTS

PAGE

TABLE

D 1 SUMMARY OF GEOLOGIC CONDITIONS AT THE SITES AND APPLIED SCALE FOR "PREDICTABILITY OF GEOLOGIC CONDITION" INDICATOR D-1

D 2 SUMMARY OF CONTAMINANT BREAKTHROUGH TIME FOR THE SITE ADAPTED LANDFILL CONTAMINANT RELEASE SCENARIO AND APPLIED SCALE FOR "CONTAMINANT BREAKTHROUGH TIME" INDICATOR D-4

D 3 SUMMARY OF CONTAMINANT BREAKTHROUGH TIME FOR THE BASE CASE PHYSICAL/CHEMICAL TREATMENT PLANT AND INCINERATOR CONTAMINANT RELEASE, SCENARIOS AND APPLIED SCALE FOR "CONTAMINANT BREAKTHROUGH TIME" INDICATOR D-5

D 4 SUMMARY OF ALTERNATIVE GROUND WATER SOURCE(S) CHARACTERISTICS AND APPLIED SCALE FOR "AVAILABILITY OF ALTERNATIVE GROUND WATER SUPPLIES" INDICATOR D-6

D 5 SUMMARY OF AQUIFER CHARACTERISTICS AT CANDIDATE SITES AND APPLIED SCALE FOR "EXISTING GROUND WATER USE AND POTENTIAL DEMAND" INDICATOR D-9

TABLE D1
SUMMARY OF GEOLOGIC CONDITIONS AT THE SITES AND APPLIED SCALE FOR "PREDICTABILITY OF GEOLOGIC CONDITION" INDICATOR

SITING OPTION	SITE	GEOLOGIC CONDITIONS		Indicator Level
		Stratigraphy	Confining Layer Uniformity	
LF-3C	LF-3C	Silt-clay (20.4 to 26.3 m thick), overlying silt-sand till (0.5 to 5.2 m thick), overlying shale and dolostone bedrock	Discontinuous, silt-fine sand laminae (1 cm thick) in upper 2 m of silt-clay; sand (2.2 m thick) noted in one borehole at 26.3 m depth	Uniform
LF-9C	LF-9C	Silt-clay (29.3 to 32.6 m thick), overlying silt-sand till (0.8 to 3.3 m thick), overlying dolostone bedrock	Discontinuous, silt-fine sand laminae (1 cm thick) in silt-clay; sand inclusions in silt-sand till	Uniform
LF-1E	LF-1E	Silt-clay (9.0 to 27.0 m thick), overlying sand and/or silt-sand till, overlying shale and dolostone bedrock; morainal feature east of site	Significant thickness of near surface granular at Walnut Hill east of site, laterally continuous granular may extend below the south central portion of site from Walnut Hill; discontinuous sand lenses within silt-clay	Locally Variable
LF-1E/ PI-27E	LF-1E	Silt-clay (9.0 to 27.0 m thick), overlying sand and/or silt-sand till, overlying shale and dolostone bedrock; morainal feature east of site	Significant thickness of near surface granular at Walnut Hill east of site, laterally continuous granular may extend below the south central portion of site from Walnut Hill; discontinuous sand lenses within silty-clay	Locally Variable
	PI-27E	Silt-clay (6.3 to 24.8 m thick), overlying sand and/or silt-sand till, overlying shale and dolostone bedrock	Discontinuous silt-fine sand laminae (10 mm thick) in silt-clay; up to 15 m thick fine sand, below 6.3 m of silt-clay, over northwestern portion of site which could extend into the confining layer within the remaining area of the site.	Locally Variable

TABLE D1
SUMMARY OF GEOLOGIC CONDITIONS AT THE SITES AND APPLIED SCALE FOR "PREDICTABILITY OF GEOLOGIC CONDITION" INDICATOR

SITING OPTION	SITE	GEOLOGIC CONDITIONS		Indicator Level
		Stratigraphy	Confining Layer Uniformity	
LF-2N/ PI-1N	LF-2N	Silt-clay till (5.1 to 11.0 m thick), overlying silt-sand till (12.1 to 27.3 m thick) with laterally continuous interbedded granular (to 2.5 m thick), overlying shale bedrock	Discontinuous sand beds (to 100 mm thick) in silt-clay till; lateral and vertical textural variability in silt-sand till portion of confining layer	Variable
	PI-1N	Silt-clay till (5.6 to 11.6 m thick) overlying clayey to sandy silt till (5.0 to 16.0 m thick) with laterally continuous interbedded granular (to 6.2 m thick), overlying shale bedrock	Discontinuous sand beds (to 140 mm thick) in silt-clay till	Uniform
LF-2N/ PI-13N	LF-2N	Silt-clay till (5.1 to 11.0 m thick), overlying silt-sand till (12.1 to 27.3 m thick) with laterally continuous interbedded granular (to 2.5 m thick), overlying shale bedrock	Discontinuous sand beds (to 100 mm thick) in silt-clay till; lateral and vertical textural variability on silt-sand till portion of confining layer	Variable
	PI-13N	Silt-clay till (3.1 to 7.1 m thick), overlying silt-sand till (2.0 to 13.2 m thick) with laterally continuous interbedded granular (to 4.1 m thick), overlying shale bedrock	Discontinuous sand beds (to 10 mm thick) in silt-clay till; silt-clay till may be locally absent	Locally Variable
LF-4N/ PI-1N	LF-4N	Silt-clay till (8.3 to 19.4 m thick), overlying variable silt-sand till (6.8 to 20.0 m thick) with laterally continuous interbedded granular (to 6.5 m thick), overlying shale bedrock	Discontinuous sand beds (to 200 mm thick) in silt-clay till	Uniform
	PI-1N	Silt-clay till (5.6 to 11.6 m thick), overlying clayey to sandy silt till (5.0 to 16.0 m thick), with laterally continuous interbedded granular (to 6.2 m thick), overlying shale bedrock	Discontinuous sand beds (to 140 mm thick) in silt-clay till	Uniform

TABLE D1
SUMMARY OF GEOLOGIC CONDITIONS AT THE SITES AND APPLIED SCALE FOR "PREDICTABILITY OF GEOLOGIC CONDITION" INDICATOR

SITING OPTION	SITE	GEOLOGIC CONDITIONS		Indicator Level
		Stratigraphy	Confining Layer Uniformity	
LF-4N/ PI-13N	LF-4N	Silt-clay till (8.3 to 19.4 m thick), overlying variable sand-silt till (6.8 to 20.6 m thick) with laterally continuous interbedded granular (to 6.5 m thick), overlying shale bedrock	Discontinuous sand beds (to 200 mm thick) in silt-clay till	Uniform
	PI-13N	Silt-clay till (3.1 to 7.1 m thick), overlying silt-sand till (2.0 to 13.2 m thick) with laterally continuous interbedded granular (to 4.1 m thick), overlying shale bedrock	Discontinuous sand beds (to 10 mm thick) in silt-clay till; silt-clay till may be locally absent	Locally Variable

Table D2 SUMMARY OF CONTAMINANT BREAKTHROUGH TIME FOR THE SITE ADAPTED LANDFILL CONTAMINANT RELEASE SCENARIO AND APPLIED SCALE FOR "CONTAMINANT BREAKTHROUGH TIME" INDICATOR

SITE	SITE ADAPTED LANDFILL DIMENSIONS		CONTAMINANT BREAKTHROUGH TIME AT BREAKTHROUGH CONCENTRATION OF C/Co = 0.1 (Years)	INDICATOR LEVEL
	Height (m)	Depth (m)		
LF-3C	4	10	600 - 1900	Long
LF-9C	4	10	1200 - 1700	Long
LF-1E (a) (b)	1.5 1.5	5 5	780 - 2500 1100	variable**
LF-2N	12	10	0* - 8	Short
LF-4N	12	10	1 - 68	Short

All breakthrough times are taken to the point of contact with the shallowest aquifer except LF-1E (b) which is taken to the point of contact with a sand layer which overlies the shallowest aquifer.

* Excavation intersects aquifer

** Indicator level based on local geologic variability identified onsite and does not apply to calculated breakthrough time value. Other sand layers may be present at shallow depth than those identified during the Phase 4A field investigation program.

TABLE D3 SUMMARY OF CONTAMINANT BREAKTHROUGH TIME FOR THE BASE CASE PHYSICAL/CHEMICAL TREATMENT PLANT AND INCINERATOR CONTAMINANT RELEASE SCENARIOS AND APPLIED SCALE FOR "CONTAMINANT BREAKTHROUGH TIME" INDICATOR

SITE	SPILL RESIDUAL SCENARIO		SUBSURFACE LEAK SCENARIO		INDICATOR LEVEL
	CONTAMINANT BREAKTHROUGH TIME (YEARS)	PEAK RELATIVE CONCENTRATION*	CONTAMINANT BREAKTHROUGH TIME (YEARS)	PEAK RELATIVE CONCENTRATION*	
LF-3C	5200	0.0013	4300	3.7×10^{-9}	Long
LF-9C	4000	0.0019	3400	7.5×10^{-9}	Long
LF-1E (a) (b)	2600 1200	0.0035 0.0096	2200 830	2.2×10^{-9} 7.9×10^{-8}	Variable **
PI-27E	2600	0.0036	2000	1.7×10^{-8}	Variable **
LF-2N	58	0.13	47	4.4×10^{-5}	Short
LF-4N	1200	0.0096	830	7.8×10^{-4}	Long
PI-1N	29	0.16	28	1.1×10^{-4}	Short
PI-13N	7	0.25	0 ***	1.0	Short

* Presented as a fraction of initial contaminant concentration

All breakthrough time and concentrations are taken to the point of contact with the shallowest aquifer except LF-1E (b) which is at a sand seam which overlies the shallowest aquifer

** Indicator Level reflects local geologic variability, does not strictly reflect calculated breakthrough time.

*** excavation intersects aquifer - contaminants in direct contact with aquifer

TABLE D4

SUMMARY OF ALTERNATIVE GROUND WATER SOURCE(S) CHARACTERISTICS AND APPLIED SCALE FOR "AVAILABILITY OF ALTERNATIVE GROUND WATER SUPPLIES" INDICATOR

SITING OPTION	SITE	ALTERNATIVE GROUND WATER SOURCE(S)	WATER QUALITY CONSIDERATIONS	WATER QUANTITY CONSIDERATIONS	INDICATOR LEVEL
LF-3C	LF-3C	upgradient bedrock (Guelph Formation)	Likely to be equal to or better in quality than that on site	Communal supplies could potentially be developed	Yes
LF-9C	LF-9C	upgradient and adjacent bedrock (Guelph Formation)	Likely to be equal to or better in quality than that available on site	Communal supplies could potentially be developed	Yes
LF-1E	LF-1E	upgradient and adjacent bedrock (Guelph and Salina Formations) or buried granular deposits	Likely to be equal to quality available on site	Communal supplies could potentially be developed	Yes
LF-1E/ PI-27E	LF-1E	upgradient and adjacent bedrock (Guelph and Salina Formations) or buried granular deposits	Likely to be equal to quality available on site	Communal supplies could potentially be developed	Yes
	PI-27E	upgradient and adjacent bedrock (Guelph and Salina Formations) or buried granular deposits	Likely to be equal to quality available on site	Communal supplies could potentially be developed	Yes

TABLE D4 (cont'd.)

SUMMARY OF ALTERNATIVE GROUND WATER SOURCE(S) CHARACTERISTICS AND APPLIED SCALE FOR "AVAILABILITY OF ALTERNATIVE GROUND WATER SUPPLIES" INDICATOR

SITING OPTION	SITE	ALTERNATIVE GROUND WATER SOURCE(S)	WATER QUALITY CONSIDERATIONS	WATER QUANITTY CONSIDERATIONS	INDICATOR LEVEL
LF-2N/ PI-1N	LF-2N	buried granular deposits in the vicinity of the site	Likely to be equal to or better in quality than that available on site	Communal supplies could potentially be developed	Yes
	PI-1N	buried granular deposits in the vicinity of the site	Likely to be equal to or better in quality than that available on site	Communal supplies could potentially be developed	Yes
LF-2N/ PI-13N	LF-2N	buried granular deposits in the vicinity of the site	Likely to be equal to or better in quality than that available on site	Communal supplies could potentially be developed	Yes
	PI-13N	alternative ground water source not available			No

TABLE D4 (cont'd.)

SUMMARY OF ALTERNATIVE GROUND WATER SOURCE(S) CHARACTERISTICS AND APPLIED SCALE FOR "AVAILABILITY OF ALTERNATIVE GROUND WATER SUPPLIES" INDICATOR

SITING OPTION	SITE	ALTERNATIVE GROUND WATER SOURCE(S)	WATER QUALITY CONSIDERATIONS	WATER QUANTITY CONSIDERATIONS	INDICATOR LEVEL
LF-4N/ PI-1N	LF-4N	buried granular deposits northwest of site	Likely to be equal to or better in quality than that available on site	Communal supplies could potentially be developed	Yes
	PI-1N	buried granular deposits west of site	Likely to be equal to or better in quality than that available on site	Communal supplies could potentially be developed	Yes
LF-4N/ PI-13N	LF-4N	buried granular deposits northwest of site	Likely to be equal to or better in quality than that available on site	Communal supplies could potentially be developed	Yes
	PI-13N	alternative ground water supplies not available			No

TABLE D5

SUMMARY OF AQUIFER CHARACTERISTICS AT CANDIDATE SITES AND APPLIED SCALE FOR "EXISTING GROUND WATER USE AND POTENTIAL DEMAND" INDICATOR

SITING OPTION	SITE	AQUIFER(S)	WATER QUALITY CONSIDERATIONS	WATER QUANTITY CONSIDERATIONS	INDICATOR LEVEL
LF-3C	LF-3C	bedrock (Salina Formation)	generally reported as 'sulphurous' and of 'poor quality'	Well yields are adequate for domestic and agricultural purposes; limited potential for communal/municipal, commercial and industrial use.	Limited
LF-9C	LF-9C	bedrock (Guelph Formation)	generally reported as 'fresh' and 'hard'; locally reported as 'sulphurous'	Well yields are adequate for domestic and agricultural purposes; potential for communal/municipal, commercial and industrial use.	Potential for Expansion
LF-1E	LF-1E	bedrock (Guelph Formation) and basal granular deposits	generally reported as 'fresh'; locally reported as 'sulphurous'	Well yields are adequate for domestic and agricultural purposes; potential for communal/municipal, commercial and industrial use.	Potential for Expansion

TABLE D5 (cont'd.)

SUMMARY OF AQUIFER CHARACTERISTICS AT CANDIDATE SITES AND APPLIED SCALE FOR "EXISTING GROUND WATER USE AND POTENTIAL DEMAND' INDICATOR

SITING OPTION	SITE	AQUIFER(S)	WATER QUALITY CONSIDERATIONS	WATER QUANTITY CONSIDERATIONS	INDICATOR LEVEL
LF-1E/ PI-27E	LF-1E	bedrock (Guelph Formation) and basal granular deposits	generally reported as 'fresh'; locally reported as 'sulphurous'	Well yields are adequate for domestic and agricultural purposes; potential for communal/municipal, commercial and industrial use.	Potential for Expansion
	PI-27E	bedrock (Guelph Formation) and basal granular deposits	generally reported as 'fresh' and 'hard'; locally reported as 'sulphurous' and 'mineralized'	Well yields are adequate for domestic and agricultural purposes; potential for communal/municipal, commercial and industrial use.	Potential for Expansion
LF-2N/ PI-1N	LF-2N	bedrock (Georgian Bay Formation) and granular deposits below the confining layer	generally reported as 'fresh' and 'hard'; locally reported as 'salty' for wells completed at depth in the bedrock	Well yields are adequate for domestic and agricultural purposes; potential for communal/municipal, commercial and industrial use.	Potential for Expansion
	PI-1N	bedrock (Queenston Formation) and granular deposits below the confining layer	generally reported as 'fresh' and 'hard'; locally reported as 'salty' for wells completed at depth in the bedrock.	Well yields are adequate for domestic and agricultural purposes; potential for larger yields is considered poor.	Limited

TABLE D5 (cont'd.)

SUMMARY OF AQUIFER CHARACTERISTICS AT CANDIDATE SITES AND APPLIED SCALE FOR "EXISTING GROUND WATER USE AND POTENTIAL DEMAND' INDICATOR

SITING SITING OPTIONS	SITE SITE	AQUIFER(S)	WATER QUALITY CONSIDERATIONS	WATER QUANTITY CONSIDERATIONS	INDICATOR LEVEL
LF-2N/ PI-13N	LF-2N	bedrock (Georgian Bay Formation) and granular deposits below the confining layer	generally reported as 'fresh' and 'hard'; locally reported as 'salty' for wells completed at depth in the bedrock	Well yields are adequate for domestic and agricultural purposes; potential for communal/ municipal, commercial and industrial use.	Potential for Expansion
	PI-13N	bedrock (Queenston Formation) and granular deposits below the confining layer	generally reported as 'fresh' and 'hard'; locally reported as 'salty' for wells completed at depth in the bedrock	Well yields are adequate for domestic and agricultural purposes; potential for larger yields is considered poor	Limited
LF-4N/ PI-1N	LF-4N	bedrock (Queenston Formation) and granular deposits below confining layer	generally reported as 'fresh' and 'hard'; locally reported as 'salty' for wells completed at depth in the bedrock	Well yields are adequate for domestic and agricultural purposes; potential for communal/ municipal, commercial and industrial use.	Potential for Expansion
	PI-1N	bedrock (Queenston Formation) and granular deposits below the confining layer	generally reported as 'fresh' and 'hard'; locally reported as 'salty' for wells completed at depth in the bedrock	Well yields are adequate for domestic and agricultural purpose; potential for larger yields is considered poor.	Limited

TABLE D5 (cont'd.)

SUMMARY OF AQUIFER CHARACTERISTICS AT CANDIDATE SITES AND APPLIED SCALE FOR "EXISTING GROUND WATER USE AND POTENTIAL DEMAND' INDICATOR

SITING OPTIONS	SITE	AQUIFER(S)	WATER QUALITY CONSIDERATIONS	WATER QUANTITY CONSIDERATIONS	INDICATOR LEVEL
LF-4N/ PI-13N	LF-4N	bedrock (Queenston Formation) and granular deposits below confining layer	generally reported as 'fresh' and 'hard'; locally reported as 'salty' for wells completed at depth in the bedrock	Well yields are adequate for domestic and agricultural purposes; potential for communal/ municipal, commercial and industrial use.	Potential for Expansion
	PI-13N	bedrock (Queenston Formation) and granular deposits below the confining layer	generally reported as 'fresh' and 'hard'; locally reported as 'salty' for wells completed at depth in the bedrock	Well yields are adequate for domestic and agricultural purposes; potential for larger yields is considered poor.	Limited